

# UNCLASSIFIED

AD NUMBER
AD869329
NEW LIMITATION CHANGE
TO Approved for public release, distribution unlimited
FROM Distribution authorized to U.S. Gov't. agencies and their contractors; Administrative/Operational use; Mar 1970. Other requests shall be referred to Vehicle Equipment Division [FDF], Air Force Flight Dynamics Laboratory, Wright-Patterson Air Force Base, Ohio
AUTHORITY
AFFDL ltr, 1 Feb 1973.

THIS PAGE IS UNCLASSIFIED

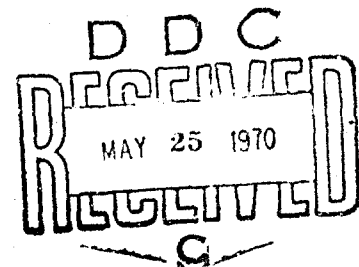
AD 869 329

## OPENING DYNAMICS OF A T-10 PARACHUTE WITH INFLATION AIDS

HELMUT G. HEINRICH  
THOMAS R. HEKTNER  
*University of Minnesota*

TECHNICAL REPORT AFFDL-TR-69-112

MARCH 1970



This document is subject to special export controls and each transmittal to foreign governments or foreign nationals may be made only with prior approval of the Vehicle Equipment Division (FDF), Air Force Flight Dynamics Laboratory, Wright-Patterson Air Force Base, Ohio. 45433

AIR FORCE FLIGHT DYNAMICS LABORATORY  
AIR FORCE SYSTEMS COMMAND  
WRIGHT-PATTERSON AIR FORCE BASE, OHIO

61

## NOTICES

When Government drawings, specifications, or other data are used for any purpose other than in connection with a definitely related Government procurement operation, the United States Government thereby incurs no responsibility nor any obligation whatsoever; and the fact that the Government may have formulated, furnished, or in any way supplied the said drawings, specifications, or other data, is not to be regarded by implication or otherwise as in any manner licensing the holder or any other person or corporation, or conveying any rights or permission to manufacture, use, or sell any patented invention that may in any way be related thereto.

This document is subject to special export controls and each transmittal to foreign governments or foreign nationals may be made only with prior approval of the Vehicle Equipment Division (FDF), Air Force Flight Dynamics Laboratory, Wright-Patterson AFB, Ohio, 45433.

The distribution of this report is limited because it contains technology identifiable with items on the strategic embargo lists excluded from export or re-export under U.S. Export Control Act of 1949 (63 STAT. 7), as amended (50 U.S.C. App. 2020.2031), as implemented by AFR 400-10.

ACCESSION for	
CPSTI	WHITE SECTION <input type="checkbox"/>
DDC	BUFF SECTION <input checked="" type="checkbox"/>
UNANNOUNCED	<input type="checkbox"/>
JUSTIFICATION	
BY	
DISTRIBUTION/AVAILABILITY CODES	
DIST.	AVAIL. and/or SPECIAL
2	

Copies of this report should not be returned unless return is required by security considerations, contractual obligations, or notice on a specific document.

# **OPENING DYNAMICS OF A T-10 PARACHUTE WITH INFLATION AIDS**

*HELMUT G. HEINRICH*

*THOMAS R. HEKTNER*

*University of Minnesota*

This document is subject to special export controls and each transmittal to foreign governments or foreign nationals may be made only with prior approval of the Vehicle Equipment Division (FDF), Air Force Flight Dynamics Laboratory, Wright-Patterson Air Force Base, Ohio.

## FOREWORD

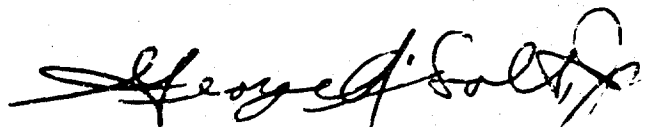
This report was prepared by the Department of Aerospace Engineering and Mechanics of the University of Minnesota in compliance with U. S. Air Force Contract No. F33615-68-C-1227, "Theoretical Deployable Aerodynamic Decelerator Investigations," Task 606503, "Parachute Aerodynamics and Structures," Project 6065, "Performance and Design of Deployable Aerodynamic Decelerators." The work on this report was performed between June 2, 1968 and June 1, 1969.

The work accomplished under this contract was sponsored jointly by U. S. Army Natick Laboratories, Department of the Army; Bureau of Aeronautics and Bureau of Ordnance, Department of the Navy; and Air Force Systems Command, Department of the Air Force, and was directed by a Tri-Service Steering Committee concerned with Aerodynamic Retardation. The work was administered under the direction of the Recovery and Crew Station Branch, Air Force Flight Dynamics Laboratory, Research and Technology Division. Mr. James H. DeWeese was the project engineer.

The study was conducted in cooperation with Mr. Robert A. Noreen and several students of Aerospace Engineering of the University of Minnesota. The authors wish to express their gratitude to all who rendered their services to the accomplishment of this work.

This report was submitted by the authors in September, 1969.

This technical report has been reviewed and is approved.



GEORGE A. SOLT, JR.  
Chief, Recovery and Crew Station Branch  
Air Force Flight Dynamics Laboratory

# ABSTRACT

The characteristic times and maximum opening forces were studied for various inflation aid configurations of a model T-10 parachute. Finite mass wind tunnel tests were conducted in the horizontal return wind tunnel at a snatch velocity of 70 fps with a suspended load of 1.1 lbs. Compared with results of the standard T-10 parachute, the percentage decrease in the characteristic time and the corresponding percentage increase in the peak force are presented for five centerline, three internal parachutes and two centerline-internal parachute combinations.

## TABLE OF CONTENTS

	PAGE
I. Introduction . . . . .	1
II. Models and Test Configurations . . . . .	2
III. Experimental Apparatus and Procedure . . . . .	13
IV. Results . . . . .	16
V. Summary . . . . .	30
VI. References . . . . .	31
VII. Appendix - Force-Time Diagrams . . . . .	32

# ILLUSTRATIONS

FIGURE		PAGE
1.	Suspended T-10 Parachute Model and Prototype with Measured Stiffness Indexes . . .	5
2.	Drag Ratio of a T-10 Parachute Model with Various Length Centerlines . . . . .	6
3.	T-10 Parachute Model, $D_o = 41.8$ Inches . .	8
4.	T-10 Parachute Model, $D_o = 41.8$ Inches with Internal Parachute, $D_I/D_o = 0.14$ . . .	9
5.	T-10 Parachute Model, $D_o = 41.8$ Inches with Centerline $L_c/D_o = 0.90$ and Internal Parachute $D_I/D_o = 0.23$ . . . . .	10
6.	Parachute Deployment Bag . . . . .	11
7.	Finite Mass Opening Shock Wind Tunnel System . . . . .	14
8.	Parachute Test Apparatus . . . . .	15
9.	Average Opening Forces vs Real Time for the T-10 Model with Various Inflation Aids.	18
10.	Projected Area-Time History of T-10 Parachute Model with and without Inflation Aids, Snatch Velocity, $V_s = 70$ fps, Mass Ratio, $m_1/m_s = 0.26^s$ . . . . .	19
11.	Force vs Time Ratios for all Inflation Aid Configurations of the T-10 Model, $D_o = 41.8$ Inches . . . . .	22
12.	Force vs Time Ratios with Their Deviations for all Inflation Aid Configurations . . . . .	23
13.	Force and Time Deviations of the T-10 Parachute Model with Inflation Aids . . . .	24
14.	Force and Time Ratios of T-10 Parachute Model with Various Centerlines . . . . .	25



# ILLUSTRATIONS (CONT.)

FIGURE		PAGE
15.	Characteristic Forces and Times of T-10 Parachute Model with Various Centerlines . . .	26
16.	Force and Time Ratios of T-10 Parachute Model with Various Internal Canopies . . . .	27
17.	Characteristic Forces and Times of T-10 Parachute Model with Various Internal Canopies . . . . .	28
18.	Force-Time History of Standard T-10 Parachute, Snatch Velocity, $V_s = 221$ fps, Suspended Weight, 210 lb, Altitude, $h = 6000$ ft . . . . .	29
19.	Force Recordings of Standard T-10 Model Parachute, $D_o = 41.8$ in . . . . .	33
20.	Force Recordings of T-10 Model with Centerline, $L_c/D_o = 1.05$ . . . . .	34
21.	Force Recordings of T-10 Model with Centerline, $L_c/D_o = 0.98$ . . . . .	35
22.	Force Recordings of T-10 Model with Centerline, $L_c/D_o = 0.90$ . . . . .	36
23.	Force Recordings of T-10 Model with Centerline, $L_c/D_o = 0.82$ . . . . .	37
24.	Force Recordings of T-10 Model with Centerline, $L_c/D_o = 0.75$ . . . . .	38
25.	Force Recordings of T-10 Model with Internal Canopy, $D_I/D_o = 0.14$ . . . . .	39
26.	Force Recordings of T-10 Model with Internal Canopy, $D_I/D_o = 0.18$ . . . . .	40
27.	Force Recordings of T-10 Model with Internal Canopy, $D_I/D_o = 0.23$ . . . . .	41
28.	Force Recordings of T-10 Model with Centerline, $L_c/D_o = 0.90$ and Internal Canopy, $D_I/D_o = 0.18$ . . . . .	42

## ILLUSTRATIONS (CONT.)

### FIGURE

### PAGE

29. Force Recordings of T-1C Model with  
Centerline,  $L_c/D_o = 0.90$  and Internal  
Canopy,  $D_I/D_o = 0.23$  . . . . . 43

# TABLES

TABLE		PAGE
I.	Physical Comparison of Model and Full Scale T-10 Parachutes . . . . .	4
II.	Model Internal Canopies . . . . .	7
III.	Dimensions of Model and Full Scale Deployment Bag . . . . .	12
IV.	Average, $\bar{t}'$ , and Dimensionless, $T^*$ , Characteristic Times for T-10 Parachute . . .	20
V.	Average, $\bar{F}_0'$ , and Dimensionless, $F^*$ , Maximum Opening Force for T-10 Parachute . .	21

# SYMBOLS

$D$	drag
$D_I$	nominal diameter of internal parachute
$D_O$	nominal diameter
$D_{max}$	maximum width of the suspended canopy
$D_{STAND}$	drag of standard T-10 model parachute
$F_O$	maximum opening force
$\bar{F}_O$	average maximum opening force of $n$ tests
$\bar{F}_{O_{STAND}}$	average maximum opening force of $n$ tests of standard T-10 parachute model
$F^*$	maximum opening force ratio, $F_O/\bar{F}_{O_{STAND}}$
$L_C$	centerline length
$L_S$	suspension line length
$m_i$	canopy included mass
$m_s$	suspended mass
$t$	instantaneous time
$t'$	characteristic time, from snatch to peak force
$\bar{t}'$	average characteristic time of $n$ tests
$\bar{t}'_{STAND}$	average characteristic time of $n$ tests of standard T-10 parachute model
$t_f$	filling time
$\bar{t}_f$	average filling time
$T$	dimensionless time, $t/t_f$
$T^*$	average characteristic time ratio, $\bar{t}'/\bar{t}'_{STAND}$
$W_c$	weight of canopy in grams
$w_{cl}$	weight of cloth per $ft^2$

$x$  distance between the plane of the mouth area of  
 the fully inflated primary and secondary parachutes  
 $\eta$  canopy stiffness index,  $\frac{D_{\max}}{D_o} \cdot \frac{W_c}{S_o \cdot w_{cl}}$   
 $\sigma$  standard deviation

## I. INTRODUCTION

For certain parachute operations a very fast opening parachute is desirable, but the opening force has to be within acceptable limits. It is known that the parachute inflation can be expedited by means of so-called inflation aids such as centerlines, internal canopies, (Ref 1); internal ballutes, (Ref 2); and combinations of centerlines with internal canopies or ballutes.

In view of practical aspects of parachute operations with inflation aids, wind tunnel tests with finite mass systems (Ref 3) were made in which the effects of centerlines, internal parachutes, and combinations of centerlines and internal chutes on the opening dynamics of a model T-10 parachute were studied. Characteristic times, force-time histories, and opening shock data were evaluated for five different centerlines, three internal parachutes, and two centerline-internal chute combinations and compared with the opening characteristics of a standard T-10 parachute. The standard filling time,  $t_f$ , from snatch force to the initially fully opened canopy shape (Ref 4) was not measured because of the effort involved and the large number of tests to be conducted. Instead a characteristic time,  $t'$ , from snatch to maximum force, was measured directly off the force-time recordings. A few test cases were performed in which the force and projected area ratios were determined as a function of dimensionless time,  $T$ . These studies indicated that the force-time characteristics for all configurations were essentially similar, and that the time interval,  $t'$ , is a characteristic feature.

The characteristic times and maximum opening forces were determined and compared with those of the standard T-10 parachute.

All finite mass opening tests were conducted with a wind tunnel dynamic pressure of  $5.2 \text{ lb/ft}^2$  or about 70 fps. The suspended weight was 1.1 lb corresponding to a ratio of included to suspended mass,  $m_i/m_s$ , of approximately 0.26. The corresponding ratio of a prototype T-10 parachute with 250 lbs suspended weight amounts to 1.18. The canopy included mass is assumed to equal the mass enclosed by a hemisphere which surface area equals  $S_0$  having a diameter of  $0.707 D_0$ .

## II. MODELS AND TEST CONFIGURATIONS

Wind tunnel tests were conducted on a 1/10 scale,  $D_o = 41.8$  in. model of a T-10 parachute with 30 gores.

Table I gives model details and a comparison to the prototype parachute. The model was built conventionally and a flexibility comparison with a full scale T-10 parachute performed as indicated in Ref 5. The suspended model T-10 with stiffness-weight indexes for both prototype and model are given in Fig 1. The internal canopies,  $D_o = 6$  in.,  $7\frac{1}{2}$  in., and  $9\frac{1}{2}$  in. were constructed of nylon cloth of 5 to 9 nominal porosity.

Wind tunnel tests of the T-10 parachute with inflation aids were conducted for the following configurations:

- A) Centerlines,  $L_c$ , which located the vent of the canopy towards the suspension line confluence point having the following lengths,  $L_c/D_o = 1.05, 0.98, 0.90, 0.82, \text{ and } 0.75$ .

These centerline ratios were chosen because respective measurements indicated that most of these configurations developed at zero degrees angle of attack considerably more drag than the standard parachute. Details of these efforts are shown in Fig 2.

- B) Internal flat circular parachutes with various diameters,  $D_I/D_o = 0.14, 0.18, \text{ and } 0.23$ , were located at  $x/D_o = 0.05, 0.03, \text{ and } 0.05$  respectively.

Table II gives a description of the internal parachutes.

- C) Centerlines combined with internal chutes:  
 $L_c/D_o = 0.90, D_I/D_o = 0.18$  and  
 $L_c/D_o = 0.90$  and  $D_I/D_o = 0.23$ .

The medium length centerline,  $L_c/D_o = 0.90$ , configuration was chosen for the centerline canopy combination because of geometric limitation in combining an internal chute with the shortest centerline and slower opening times with the longer centerlines.

Profile and frontal views of the T-10 standard with and without inflation aids can be seen in Figs 3, 4, and 5.

A deployment bag as shown in Fig 6 was used in all wind tunnel tests. Its dimensions as well as those of the full size deployment bag are given in Table III.



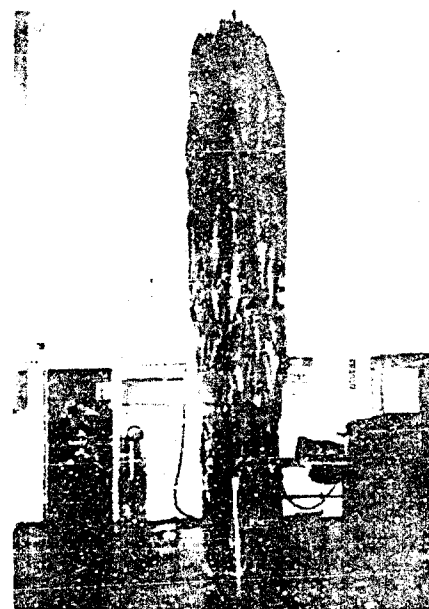
**TABLE I**  
**PHYSICAL COMPARISON OF MODEL**  
**AND FULL SCALE T-10 PARACHUTES**

Physical Parameters	Model	Prototype*
$D_o$	41.8 in	35 ft
Suspended Load	1.1 lb**	250 lb
Canopy Weight***	0.14 lb	11.70 lb
Canopy Material	1.1 oz Ripstop Nylon MIL-C-7020D, Type I	
Suspension Lines	50 lb Nylon	MIL-C-5040 Type II
Suspension Line Length, $L_s$	30.6 in	25.5 ft
Riser Length	3.6 in	3 ft

\*Ref 6

\*\*includes cable

\*\*\*includes suspension lines



	Model T-10, $D_o = 41.8$ in	Full Scale* T-10, $D_o = 35$ ft.
$D_{max}$	13.3 in	2.62 ft.
$\frac{D_{max}}{D_o}$	0.32	0.075
$W_c^{**}$	65 gm	5310 gm
$\eta$	0.63	0.12

\*Suspended at Wright-Patterson AFB, Ohio

\*\*Includes suspension lines

Fig.1 Suspended T - 10 Parachute Model and Prototype with Measured Stiffness Indexes.

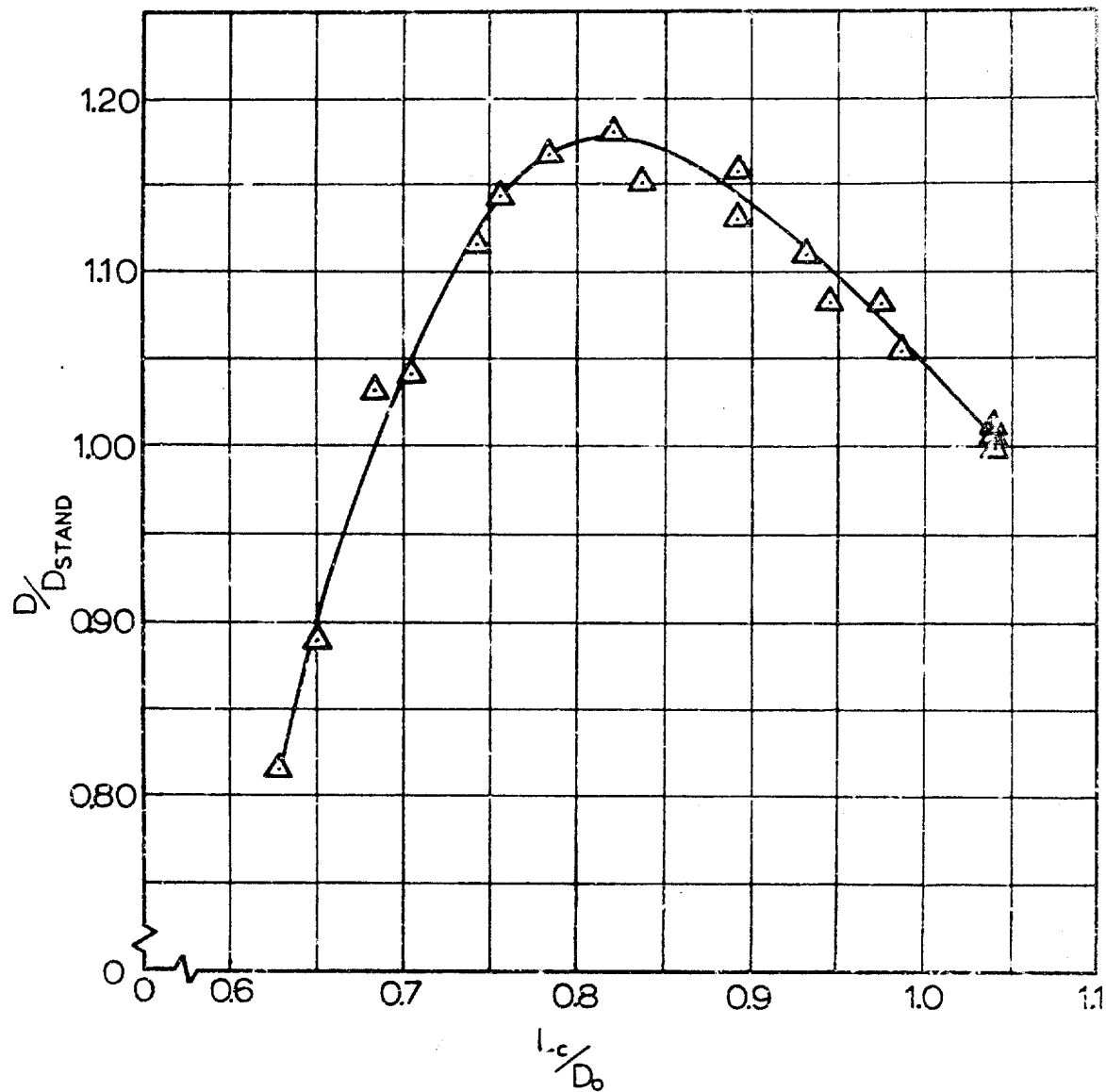


Fig 2 Drag Ratio of a T-10 Parachute Model with Various Length Centerlines.

TABLE II  
MODEL INTERNAL CANOPIES

Physical Parameters	Internal Canopies		
Nominal diameter, $D_I$ (inches)	6.0	7.5	9.5
Canopy Material	Nylon 5 to 9 nominal porosity		
Canopy Weight (grams)	1.3	3.1	4.9
Suspension Lines	50 lb Nylon cord		
Suspension Line Length (inches)	6.0	7.5	9.5
$D_I/D_O$	0.14	0.18	0.23
No. of Gores	4	5	6

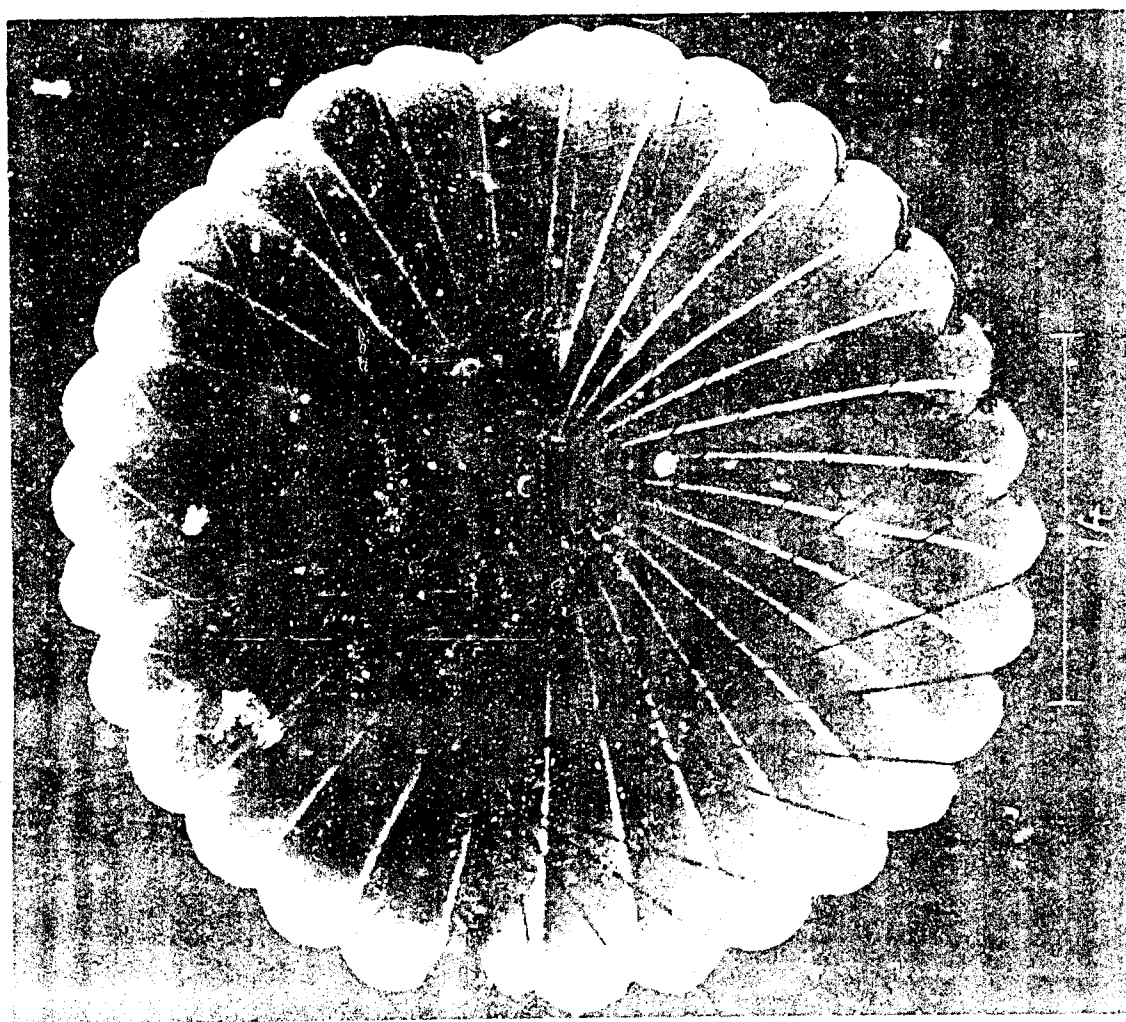
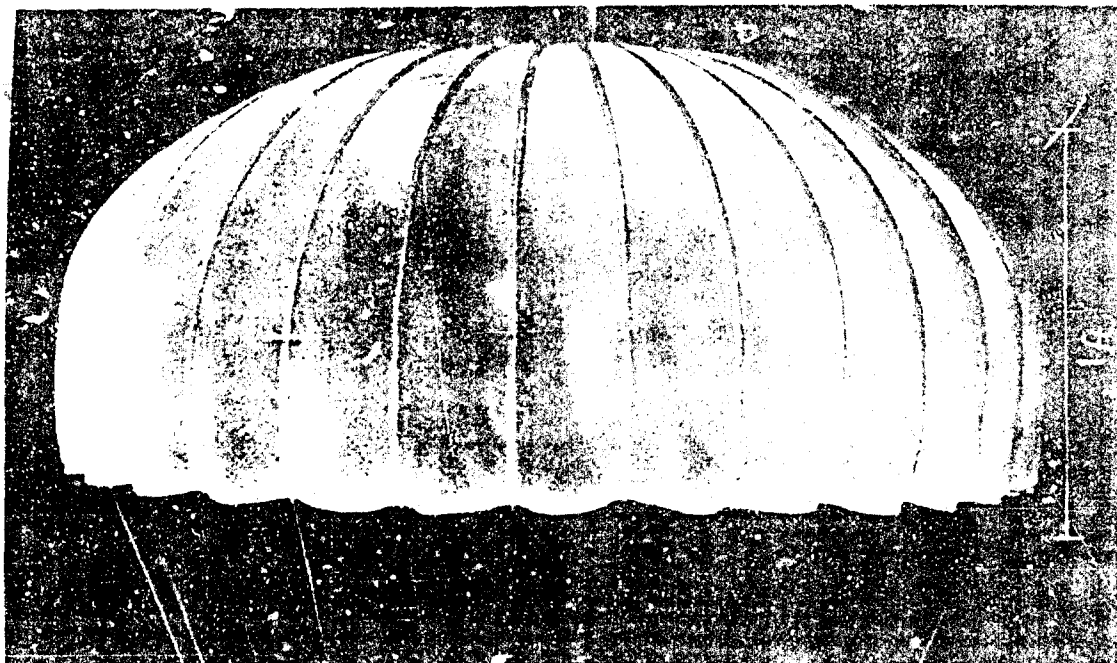


Fig. 3 T-10 Parachute Model,  $D_0 = 41.8$  in

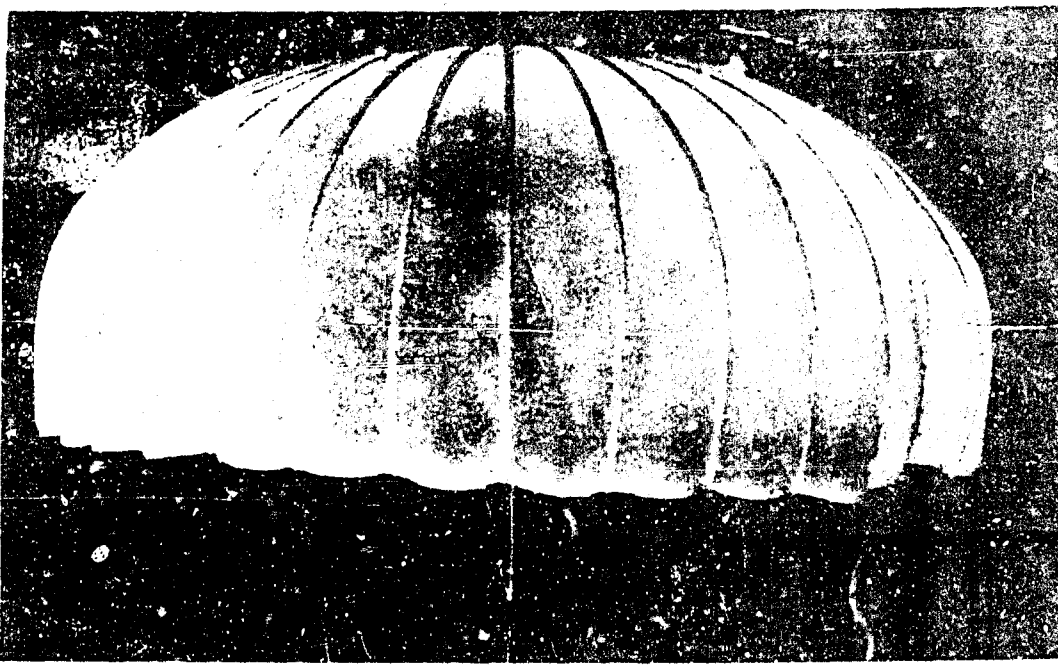
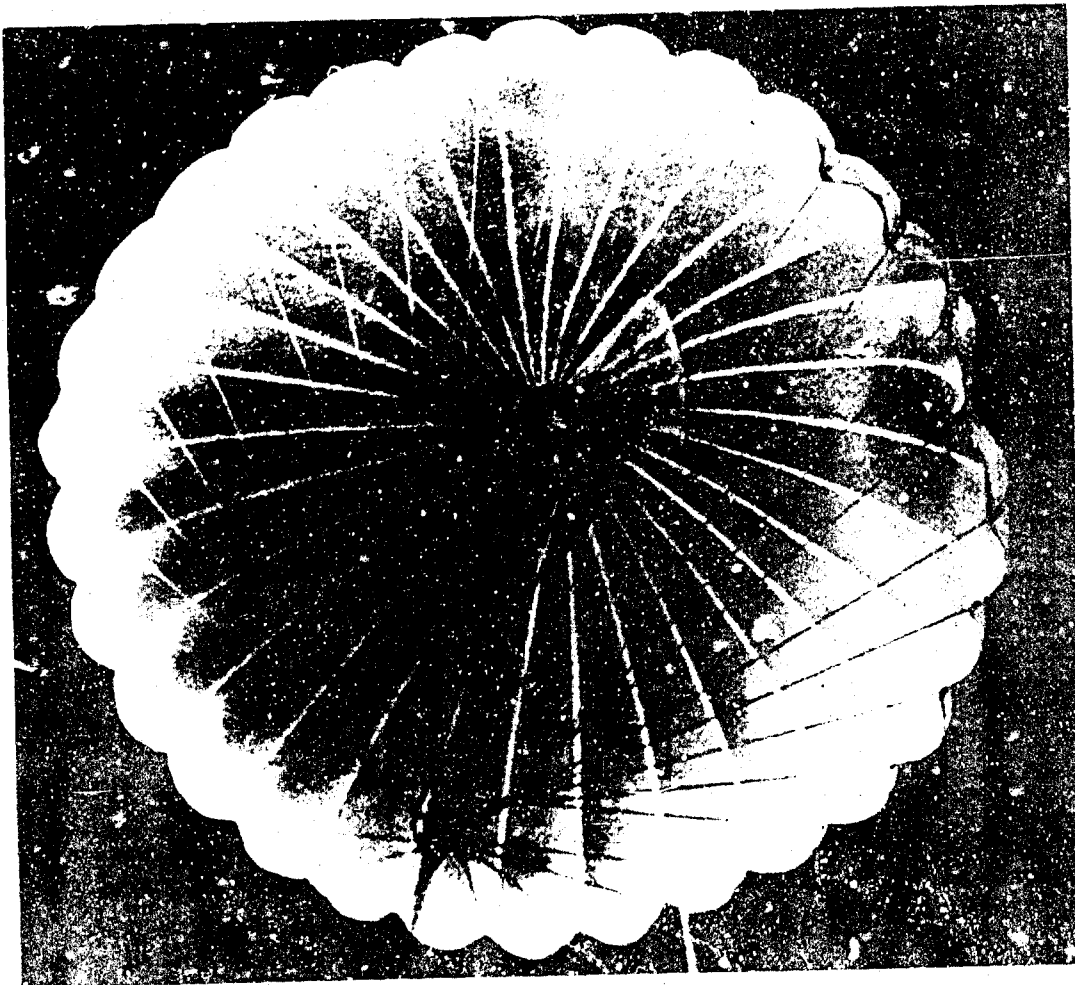


Fig.4 T-10 Parachute Model,  $D_O = 41.8$  in with Internal  
Parachute,  $D_I/D_O = 0.14$

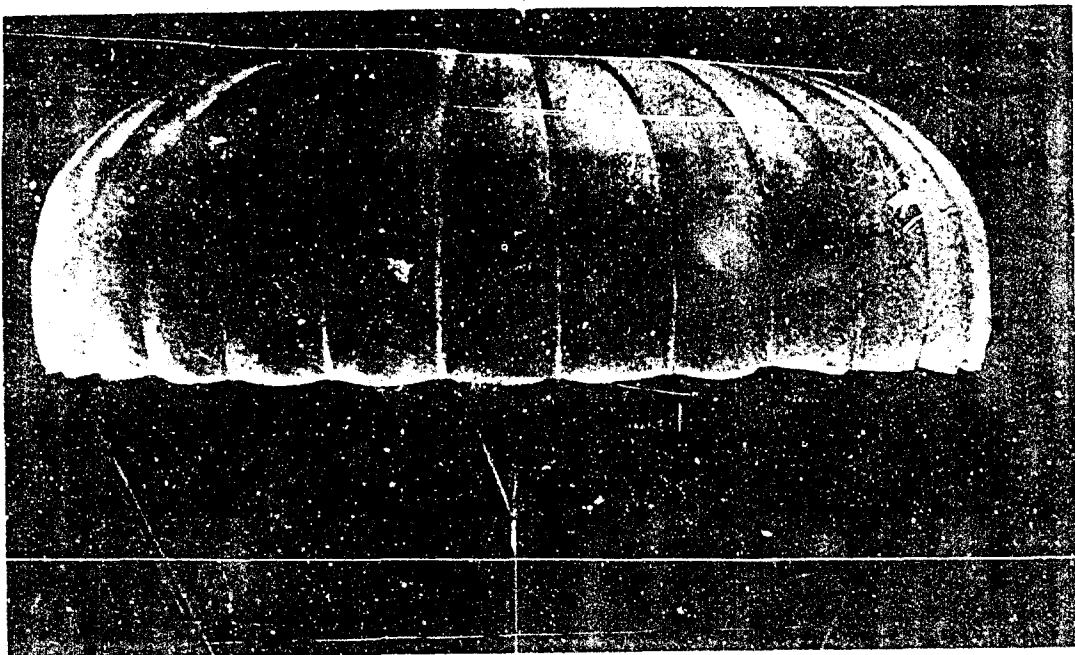
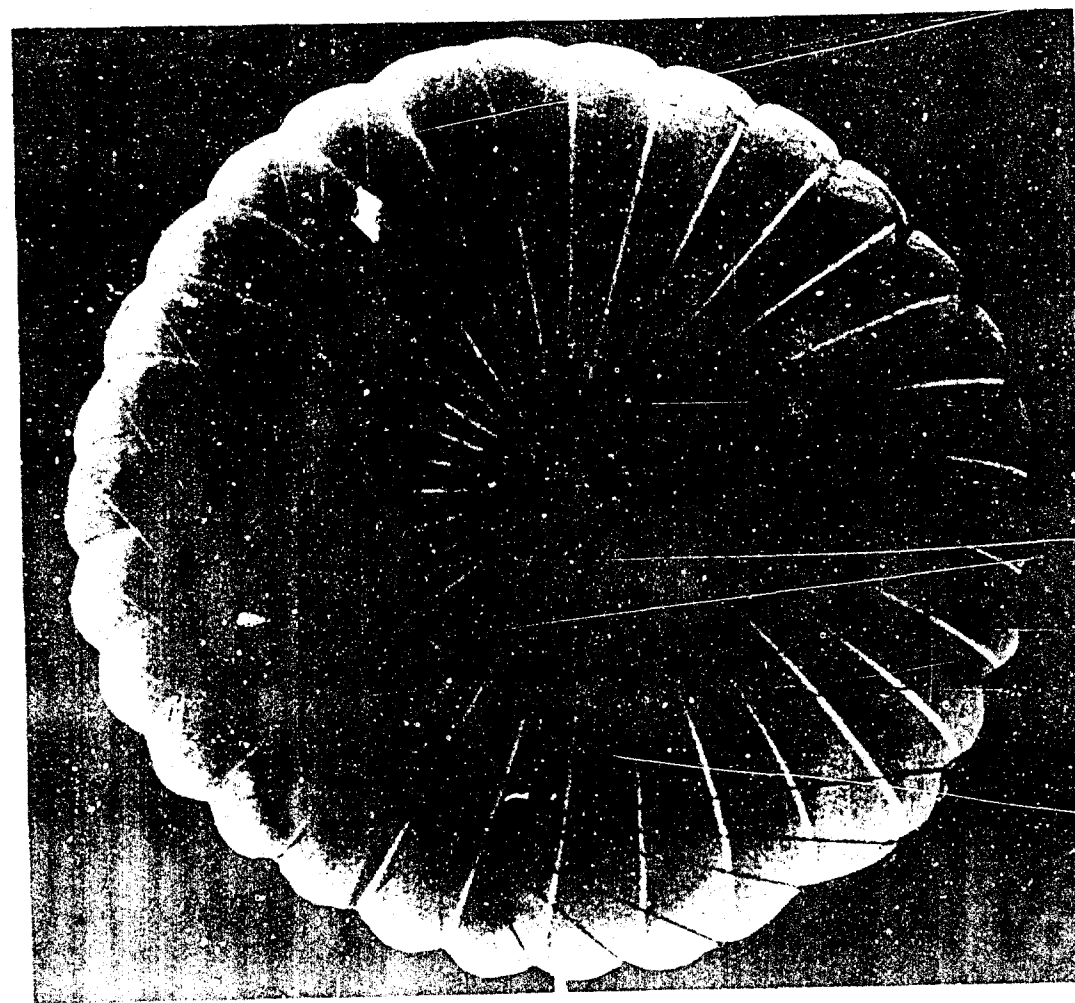


Fig. 5 T-10 Parachute Model,  $D_o = 41.8$  in with Centerline,  
 $L_c/D_o = 0.90$  and Internal Parachute,  $D_i/D_o = 0.23$

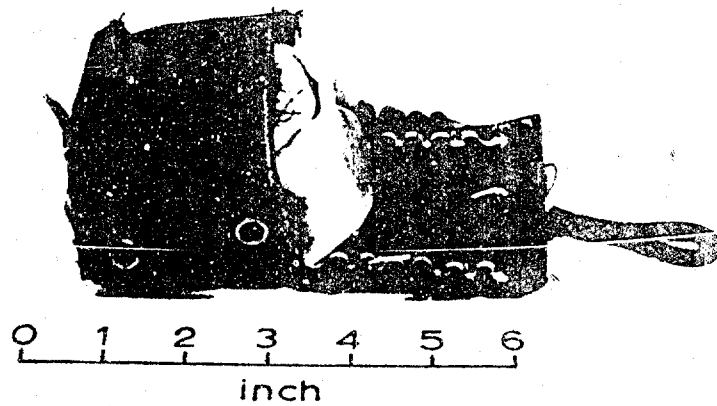


Fig 6a Parachute Enclosed in Bag



Fig 6b Bag Unfolded

Fig. 6 Parachute Deployment Bag



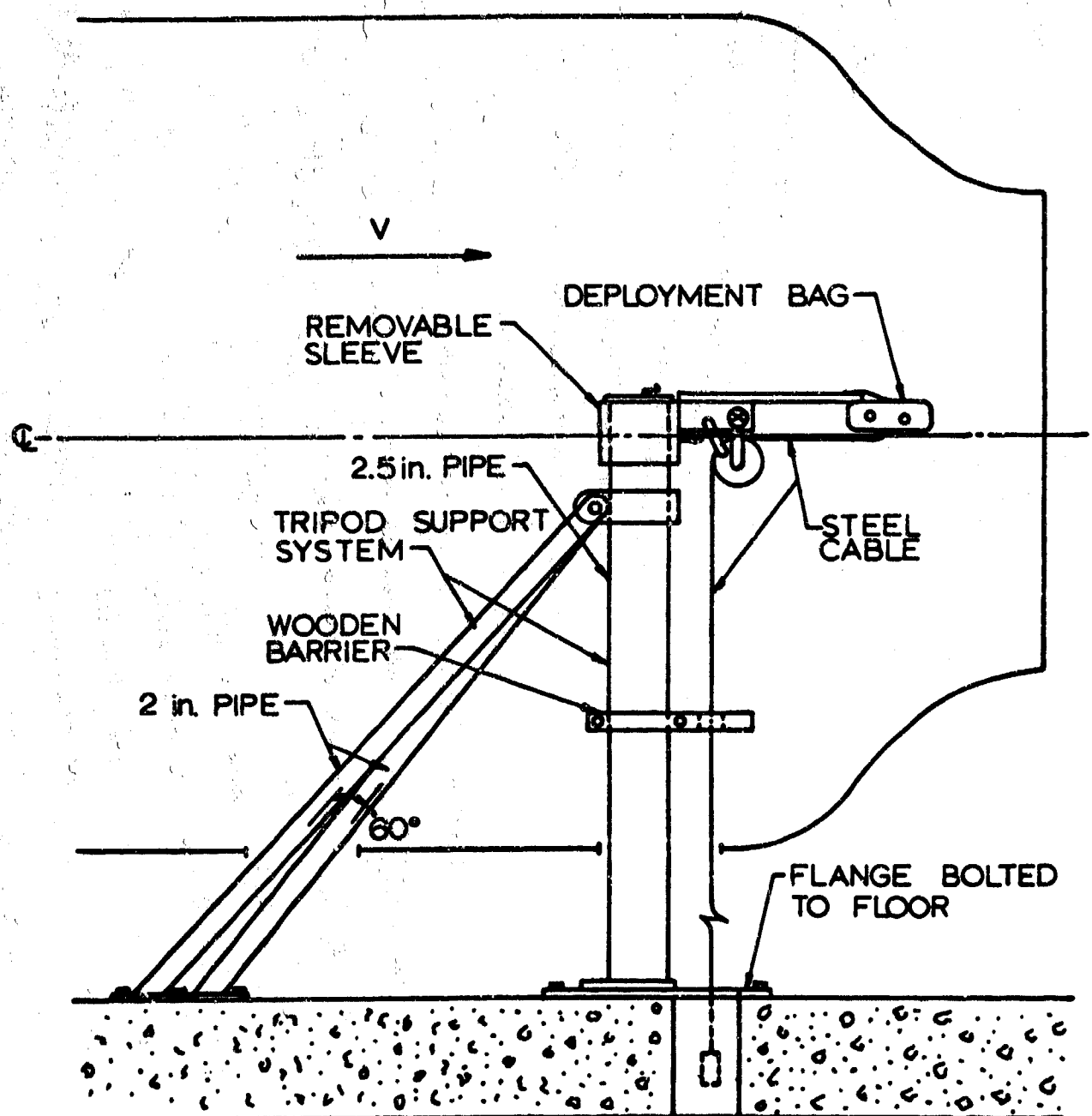
TABLE III  
 DIMENSIONS OF MODEL AND FULL  
 SCALE DEPLOYMENT BAG

Bag Dimensions	Model	Prototype
Length (in)	3.4	22
Width (in)	3.2	12
Height (in)	1.7	5

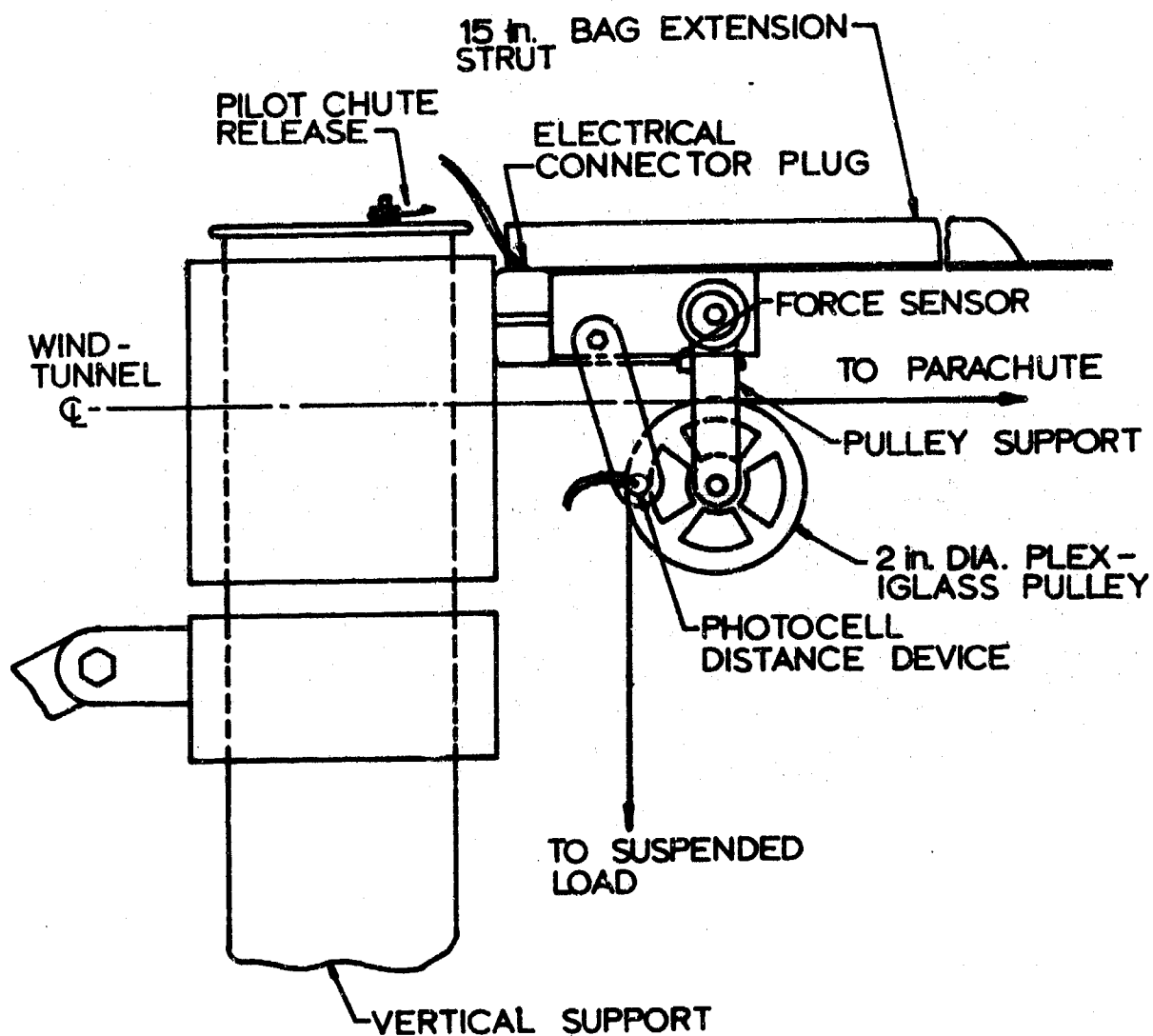
### III. EXPERIMENTAL APPARATUS AND PROCEDURE

All configurations of the T-10 were packed in an accordion-like fashion for a lines first deployment.

Following the deployment by an inflated pilot parachute, the main T-10 canopy traveled downstream as dictated by the aerodynamic forces and was restrained only by the 1.1 lb. suspended payload weight connected by means of cable over the pulley force sensor, Figs 7 and 8. Instantaneous forces were measured by means of a strain gage attached to a tension member incorporated in the pulley support and recorded versus a time scale on the diagram of a Honeywell visicorder. Front and side movies were taken during at least two runs of each configuration and the photocell distance device was operated for all tests to provide velocity indications. Related to the parachute canopy diameter, the Reynolds Number of the tests was  $1.56 \times 10^6$ . In order to provide reliable average values at least 10 valid tests were evaluated and the results shown below represent such averages.



**Fig 7** Finite Mass Opening Shock Windtunnel System



**Fig 8 Parachute Test Apparatus**

#### IV. RESULTS

The test evaluations provided diagrams as shown in Fig 9. The curves shown represent average values obtained from five individual tests. The filling times related to the instant at which the projected area equals for the first time the projected area under steady state conditions,  $T = 1$ , are marked. The values were obtained from an area-time analysis as shown in Fig 10. A further analysis also indicated that the ratios  $\bar{T}'/\bar{T}_f$  of all configurations were about the same. Therefore, it was concluded that the value  $\bar{T}'$  could be taken as characteristic for the rate of the canopy inflation.

Figure 9 indicates that with inflation aids the opening time of the T-10 parachute is shorter but that this time saving is connected with a significant increase in opening force. Furthermore, it is noticed that a relatively short centerline reduces the opening time materially and that a combination of a centerline and an internal canopy provides opening times,  $t_f$ , or characteristic times,  $\bar{T}'$ , less than half as long as those of the standard T-10 parachute.

These and additional information are given numerically in Tables IV and V. In these tables one notices that the relatively short centerlines of  $L_c/D_o = 0.90, 0.82, \text{ and } 0.75$  provide about the same short time intervals as the three internal canopies (Table IV), but that the internal canopies produce smaller maximum forces (Table V). Combinations of centerlines and internal canopies reduce the time further but raise relatively high opening forces.

The most important results are shown in more detail and maybe in more impressive form in Figs 11 and 12. For example, Fig 11 indicates that for certain given times the T-10 parachute canopy produces higher forces with centerlines than with internal parachutes. Figure 12 shows that the T-10 parachute with inactive or long centerlines has the highest time deviations but lower force deviations than the same canopy with shorter centerlines or internal canopies.

Figures 13 through 17 are back-up data showing the individual curves and their specific deviations. For comparison a force-time diagram of a full size test is also included (Fig 18). The form of this diagram differs slightly from those averaged model diagrams of Fig 9. This difference may be caused by the relative model stiffness and the difference of included to suspended masses of the model and the full size parachute (Ref 5). Further supporting data are

given in the appendix in the form of originally recorded force-time diagrams. These data give qualitative information on the same nature as gained from the numerical evaluation. Also stability pendulum tests were made, but all configurations moved so much at random that conclusive statements cannot be made.

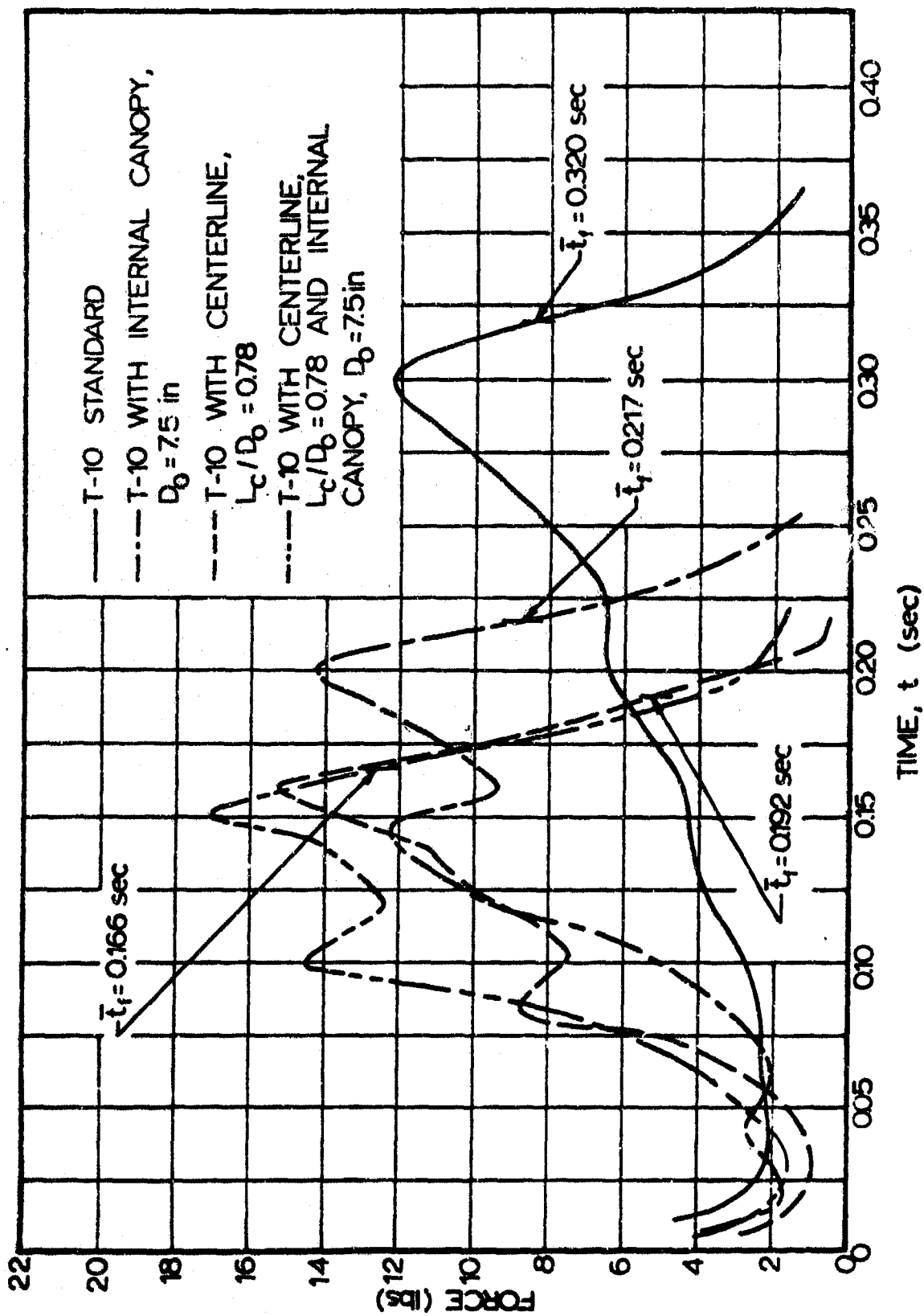


Fig 9 Average Opening Forces vs Real Time for the T-10 Model with Various Inflation Aids

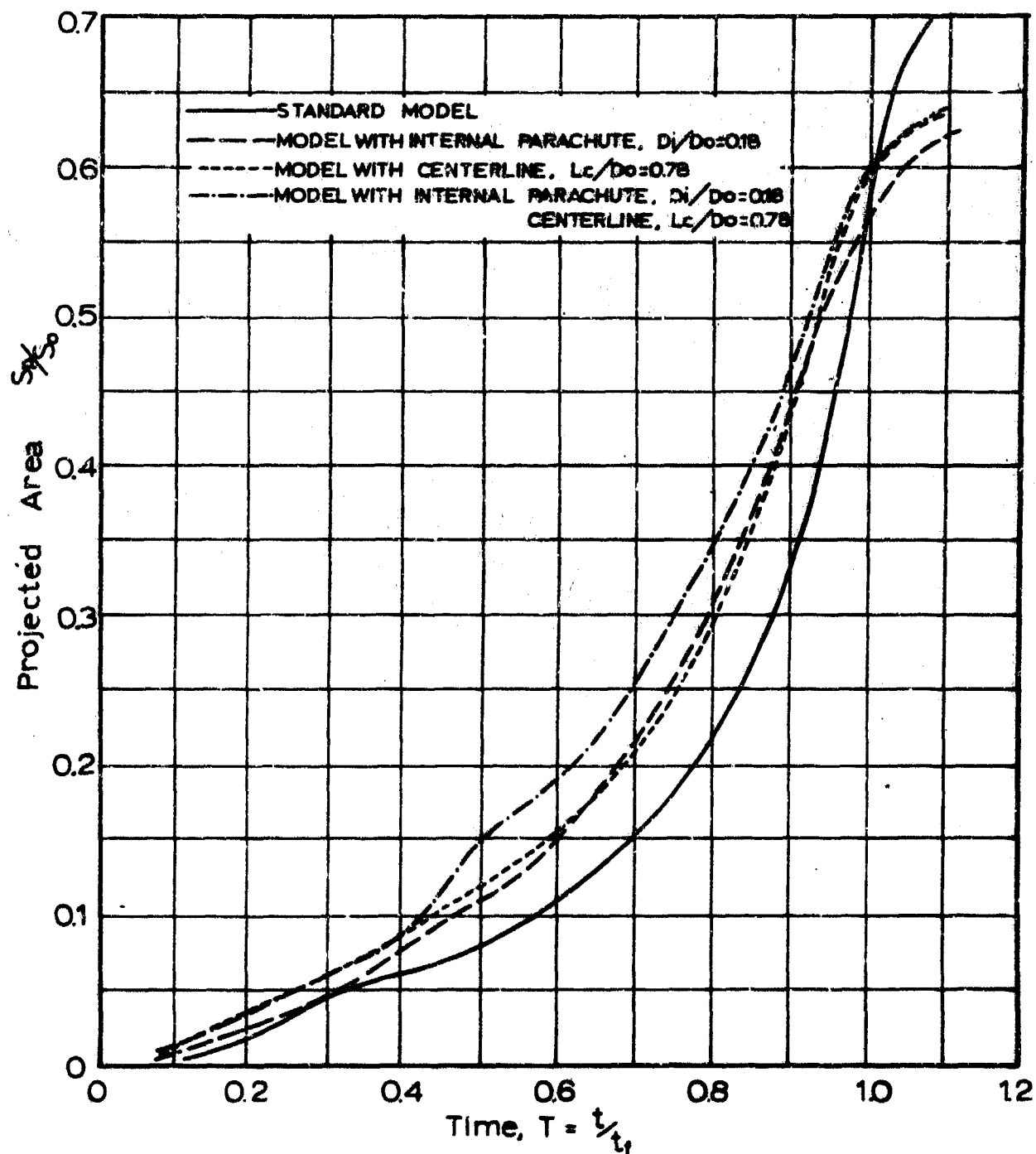


Fig 10 Projected Area -Time History of T-10 Parachute Model with and without Inflation Aids, Snatch Velocity  $V_s = 70$  fps, Mass Ratio  $m_i/m_s = 0.26$ .



**TABLE IV**  
**AVERAGE,  $\bar{t}$ , AND DIMENSIONLESS,  $T^*$ , CHARACTERISTIC TIMES FOR T-10 PARACHUTES**

Configuration	No. Tests	$\bar{t} \pm \sigma$ (sec)	$T^* = \bar{t}/\bar{t}_{STD} \pm \sigma$
Standard	12	$0.272 \pm 0.044$	$1.000 \pm 0.161$
Centerlines			
$L_c/D_o = 1.05$	9	$0.284 \pm 0.034$	$1.044 \pm 0.125$
$L_c/D_o = 0.98$	10	$0.189 \pm 0.048$	$0.695 \pm 0.176$
$L_c/D_o = 0.90$	10	$0.142 \pm 0.043$	$0.522 \pm 0.158$
$L_c/D_o = 0.82$	10	$0.164 \pm 0.029$	$0.603 \pm 0.143$
$L_c/D_o = 0.75$	10	$0.129 \pm 0.019$	$0.474 \pm 0.070$
Internal Parachute			
$D_I/D_o = 0.14$	14	$0.137 \pm 0.032$	$0.504 \pm 0.118$
$D_I/D_o = 0.18$	11	$0.147 \pm 0.041$	$0.540 \pm 0.151$
$D_I/D_o = 0.23$	13	$0.128 \pm 0.018$	$0.470 \pm 0.066$
Centerline and Internal Chute			
$L_c/D_o = 0.90$ $D_I/D_o = 0.18$	11	$0.120 \pm 0.017$	$0.441 \pm 0.062$
$L_c/D_o = 0.90$ $D_I/D_o = 0.23$	12	$0.119 \pm 0.021$	$0.438 \pm 0.077$

$$\sigma = \left[ \frac{\sum (x_i - \bar{x})^2}{n} \right]^{1/2}$$

$$*D_o = 41.76 \text{ in}$$

TABLE V  
AVERAGE,  $\bar{F}_0$ , AND DIMENSIONLESS,  $F^*$ ,  
MAXIMUM OPENING FORCE FOR T-10  
PARACHUTE

Configuration	No. Tests	$\bar{F}_0 \pm \sigma$ (lb)	$F^* = \bar{F}_0 / \bar{F}_{STD} \pm \sigma$
Standard	12	$13.2 \pm 1.9$	$1.000 \pm 0.144$
Centerline			
$L_c/D_o = 1.05$	9	$11.9 \pm 2.6$	$0.902 \pm 0.197$
$L_c/D_o = 0.98$	10	$16.2 \pm 2.5$	$1.227 \pm 0.189$
$L_c/D_o = 0.90$	10	$18.8 \pm 3.0$	$1.424 \pm 0.227$
$L_c/D_o = 0.82$	10	$18.8 \pm 2.7$	$1.424 \pm 0.205$
$L_c/D_o = 0.75$	10	$21.2 \pm 2.7$	$1.606 \pm 0.205$
Internal Parachute			
$D_I/D_o = 0.14$	14	$17.5 \pm 1.6$	$1.326 \pm 0.121$
$D_I/D_o = 0.18$	11	$16.3 \pm 3.1$	$1.235 \pm 0.235$
$D_I/D_o = 0.23$	13	$20.2 \pm 1.9$	$1.530 \pm 0.144$
Centerline and Internal Chute			
$L_c/D_o = 0.90$ $D_I/D_o = 0.18$	11	$22.1 \pm 2.3$	$1.674 \pm 0.174$
$L_c/D_o = 0.90$ $D_I/D_o = 0.23$	12	$21.5 \pm 2.3$	$1.629 \pm 0.174$

$$\sigma = \left[ \frac{\sum (x_i - \bar{x})^2}{n} \right]^{\frac{1}{2}}$$

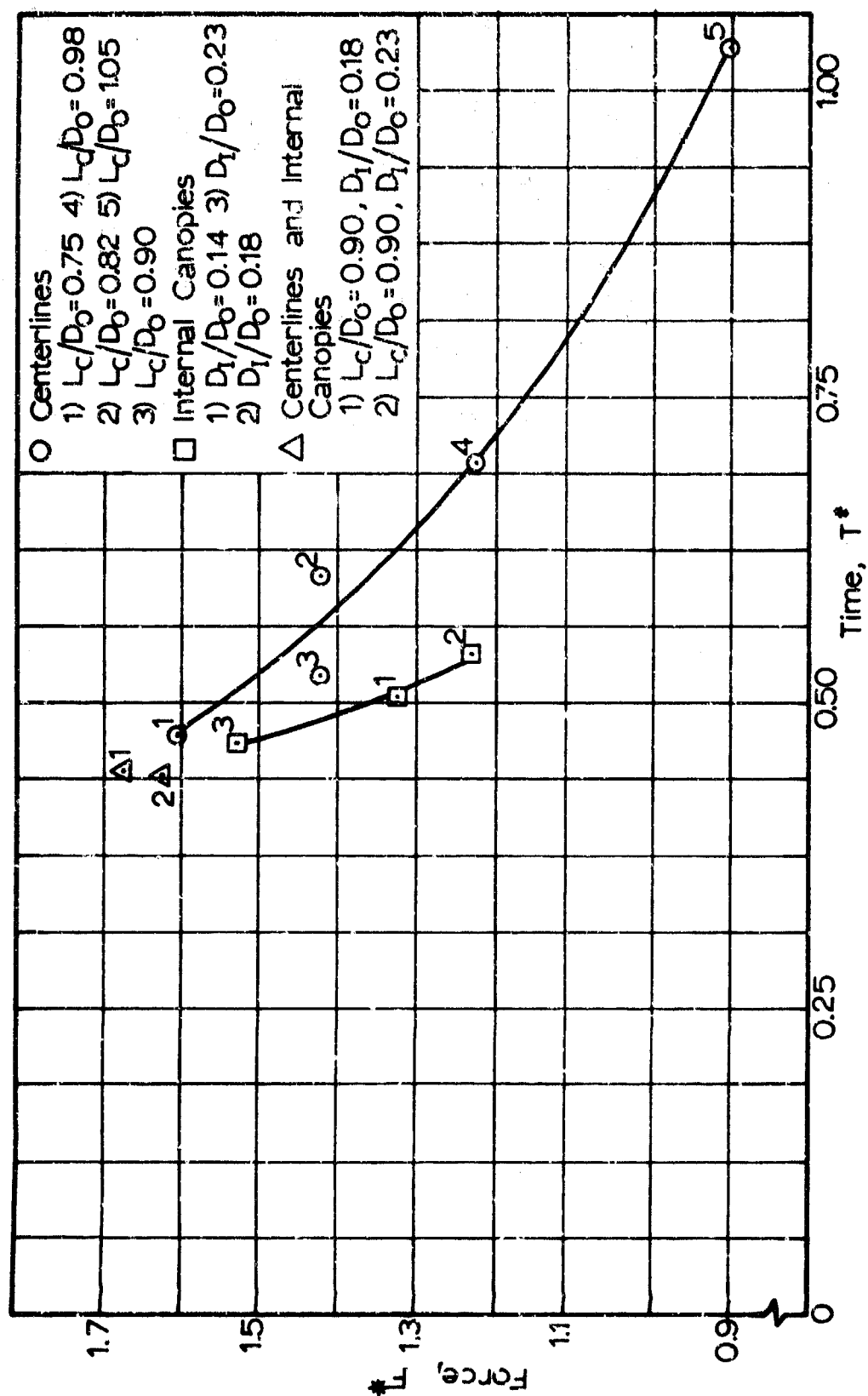


Fig11 Force vs Time Ratios for All Inflation Aid Configurations of the T-10 Model,  $D_0 = 41.8$  in

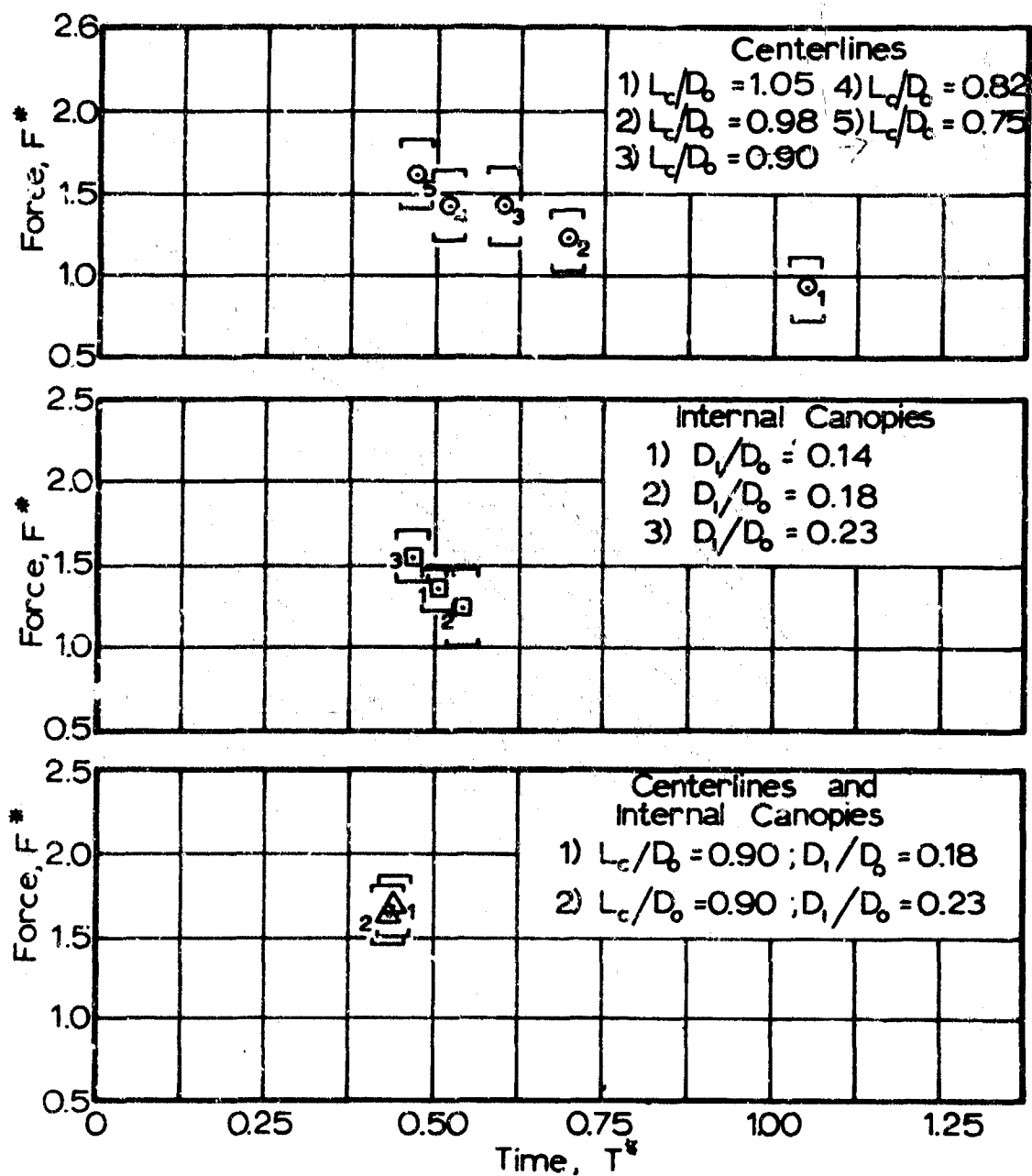
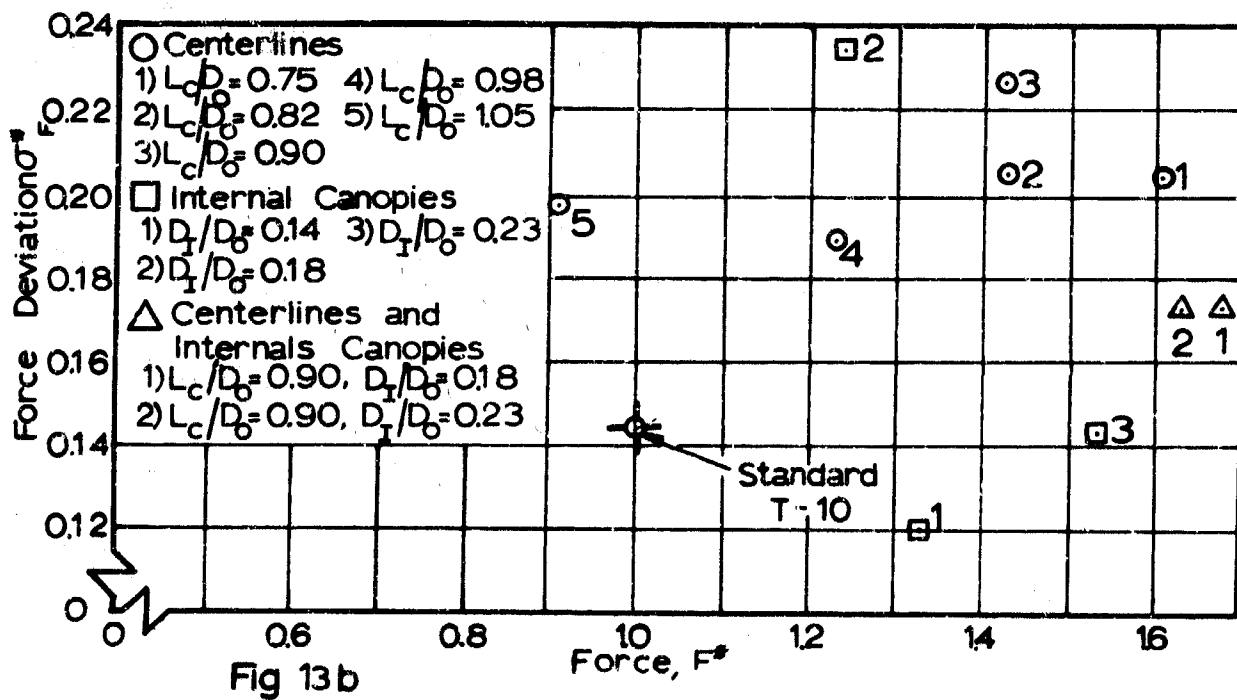
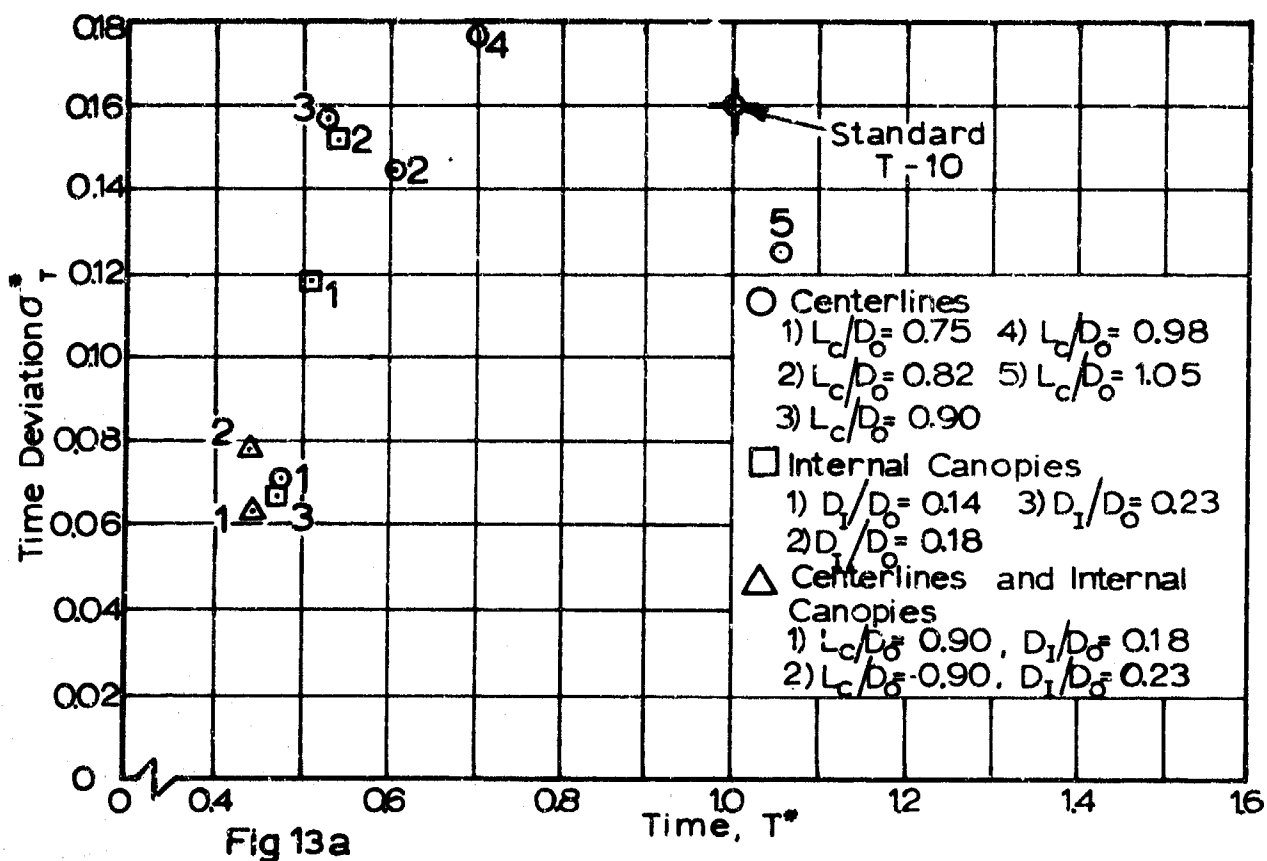


Fig. 12 Force vs. Time Ratios with Their Deviations for all Inflation Aid Configurations



**Fig 13 Force and Time Deviations of the T-10 Parachute Model with Inflation Aids**

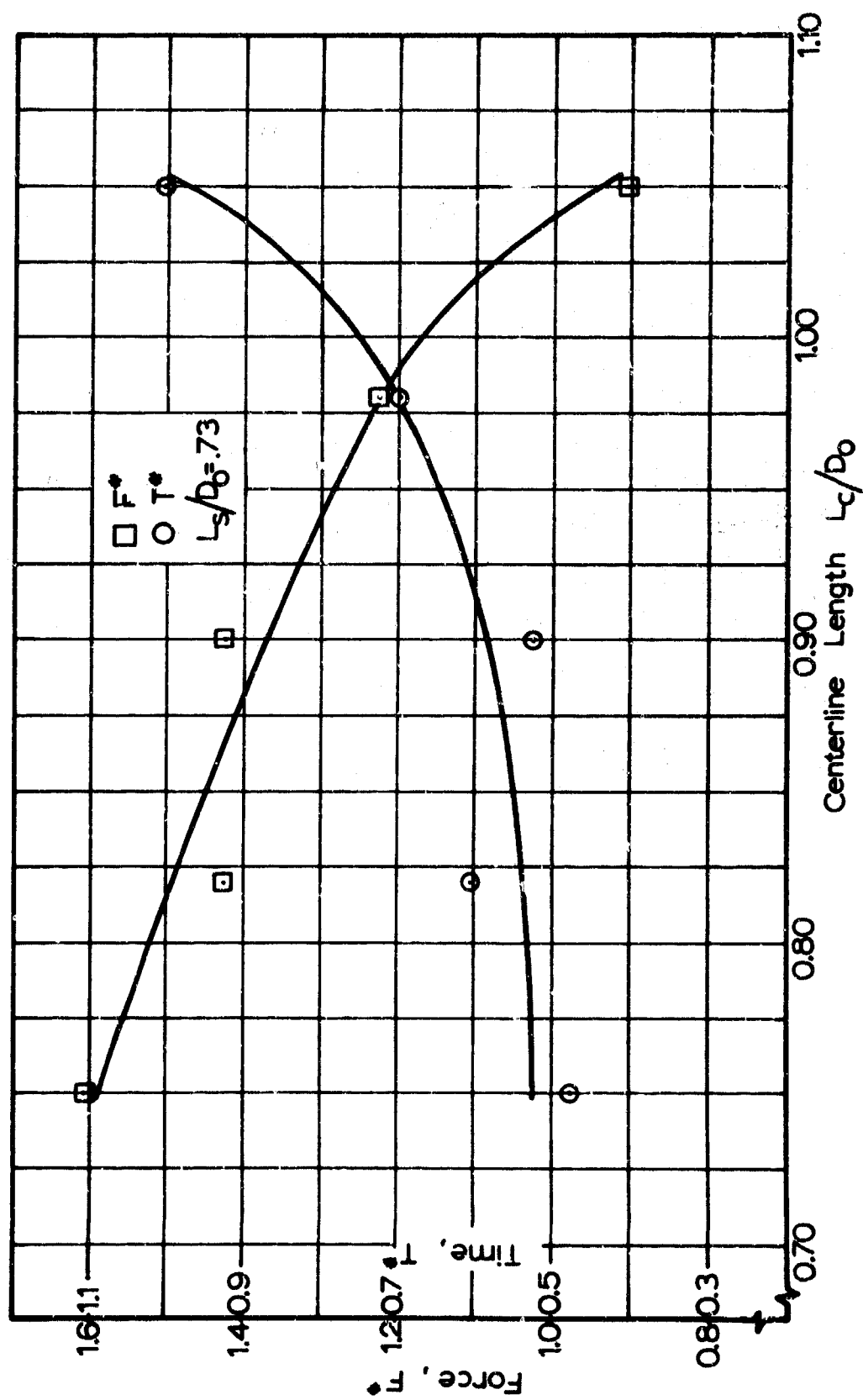


Fig 14 Force and Time Ratios of T-10 Parachute Model  
with Various Centerlines

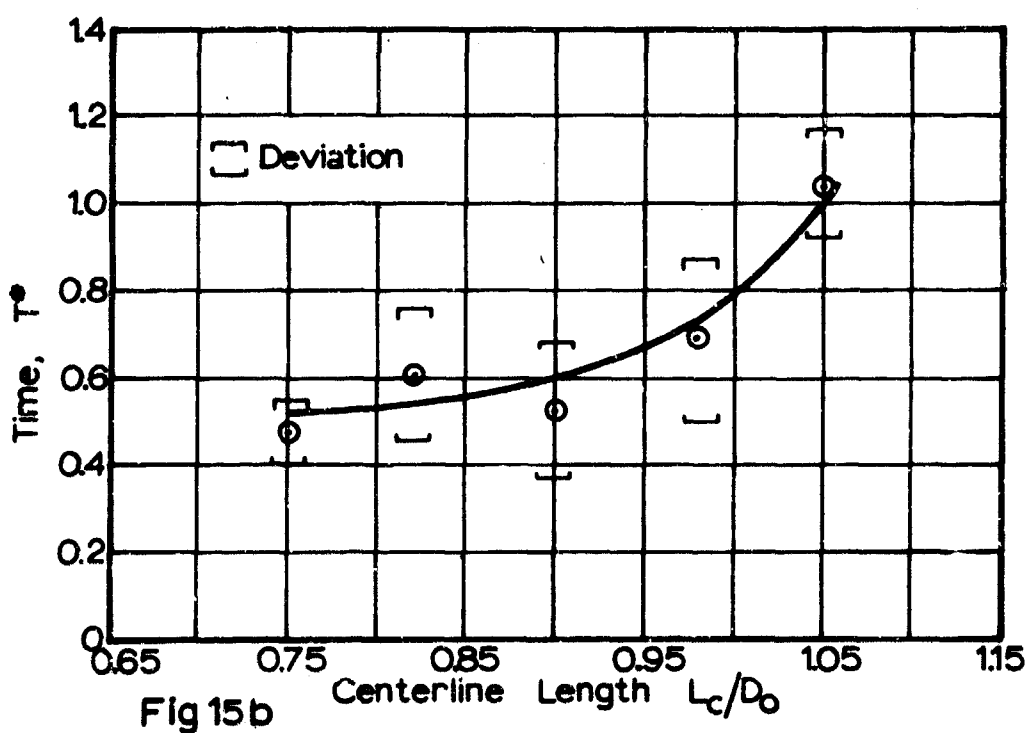
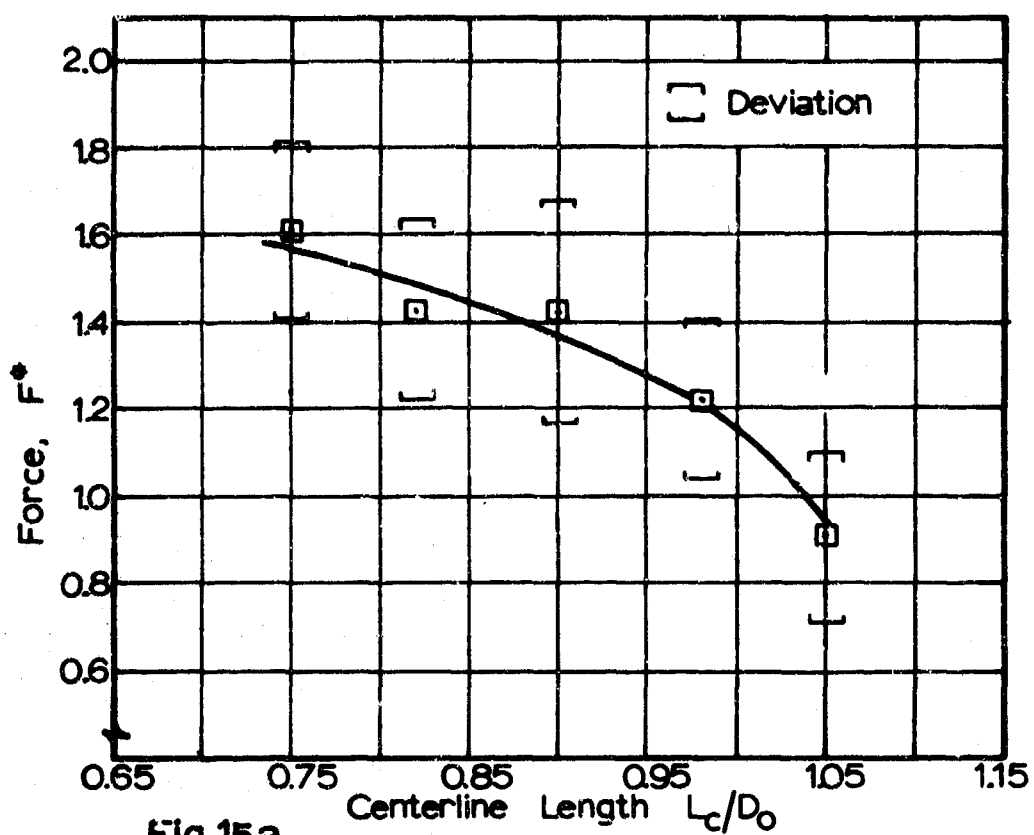


Fig 15 Characteristic Forces and Times of T-10 Parachute Model with Various Centerlines

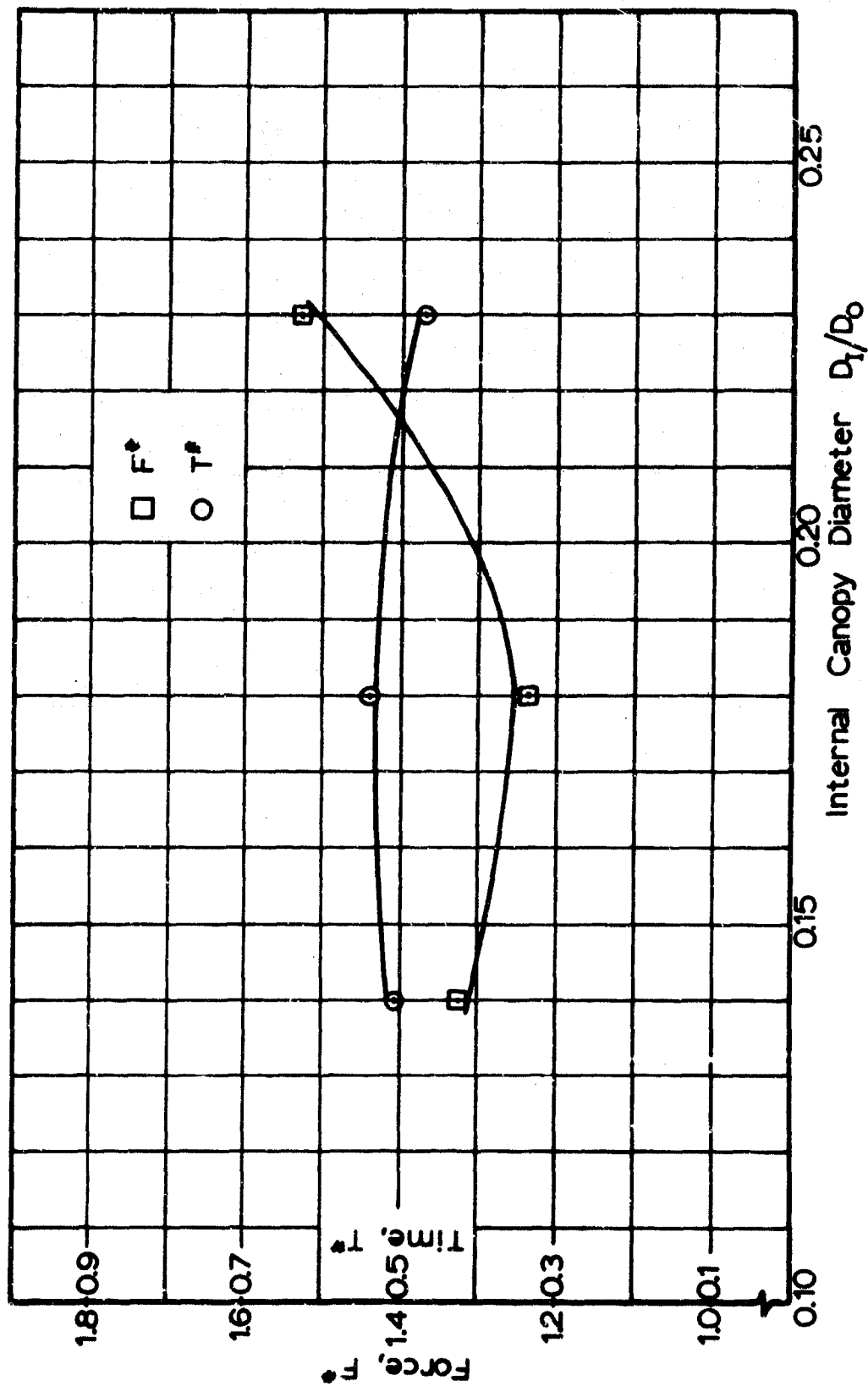


Fig16 Force and Time Ratios of T-10 Parachute Model  
with Various Internal Canopies



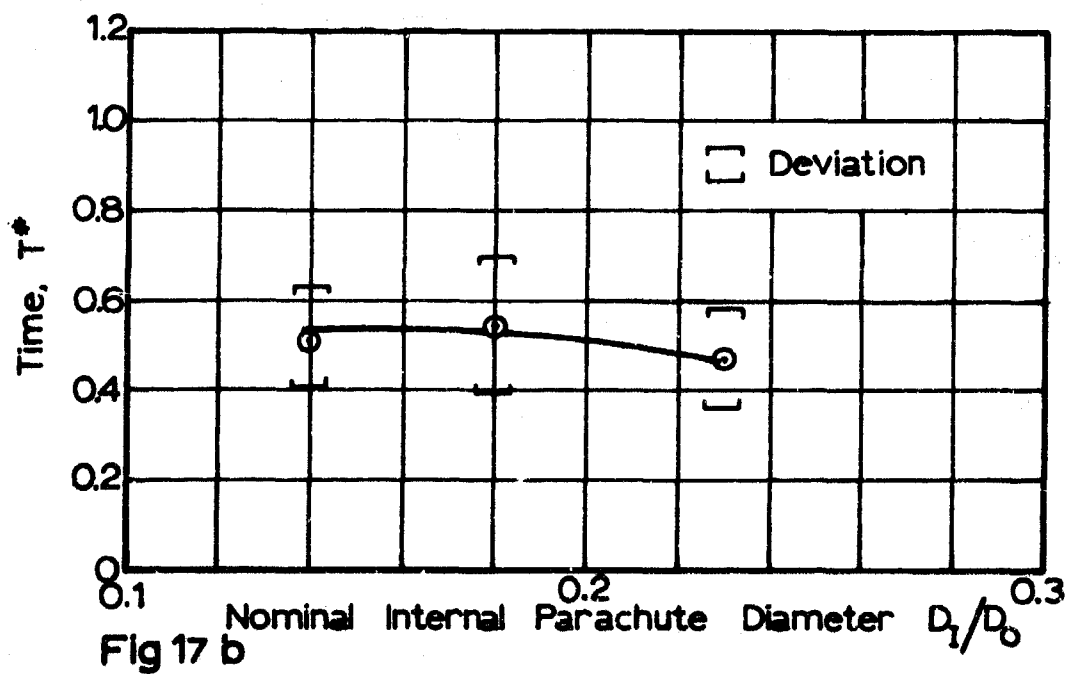
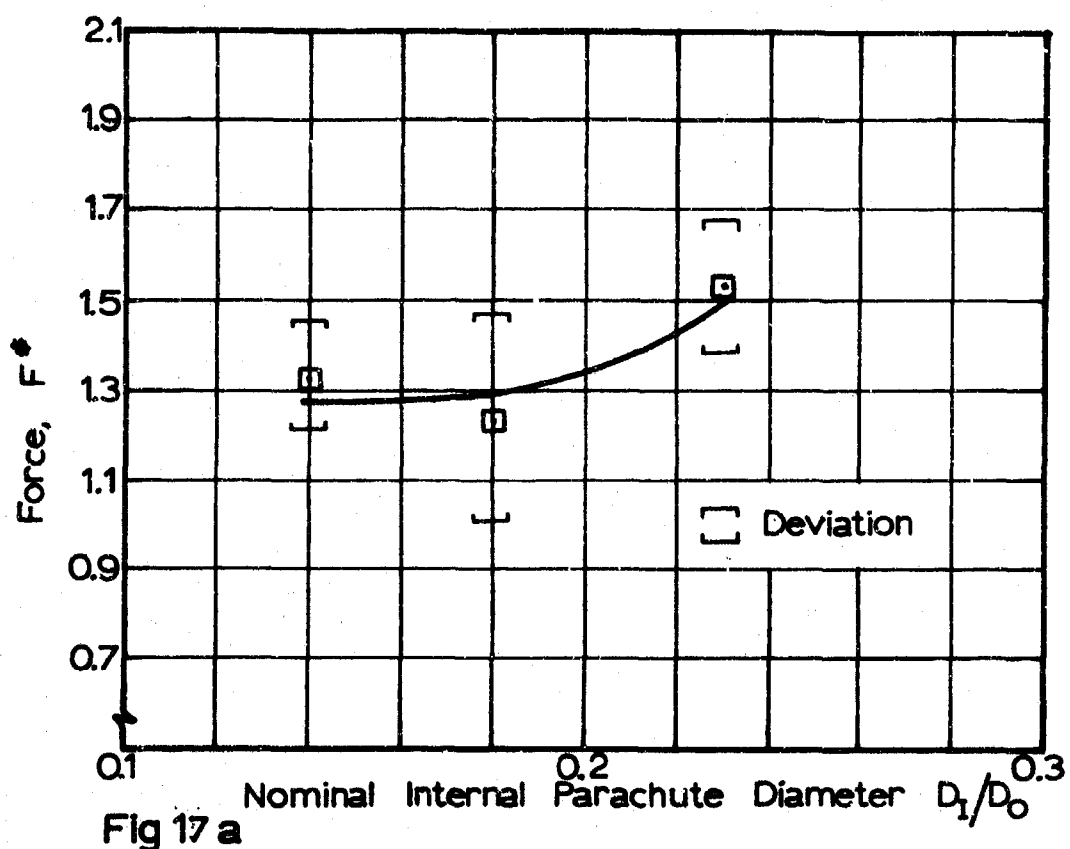
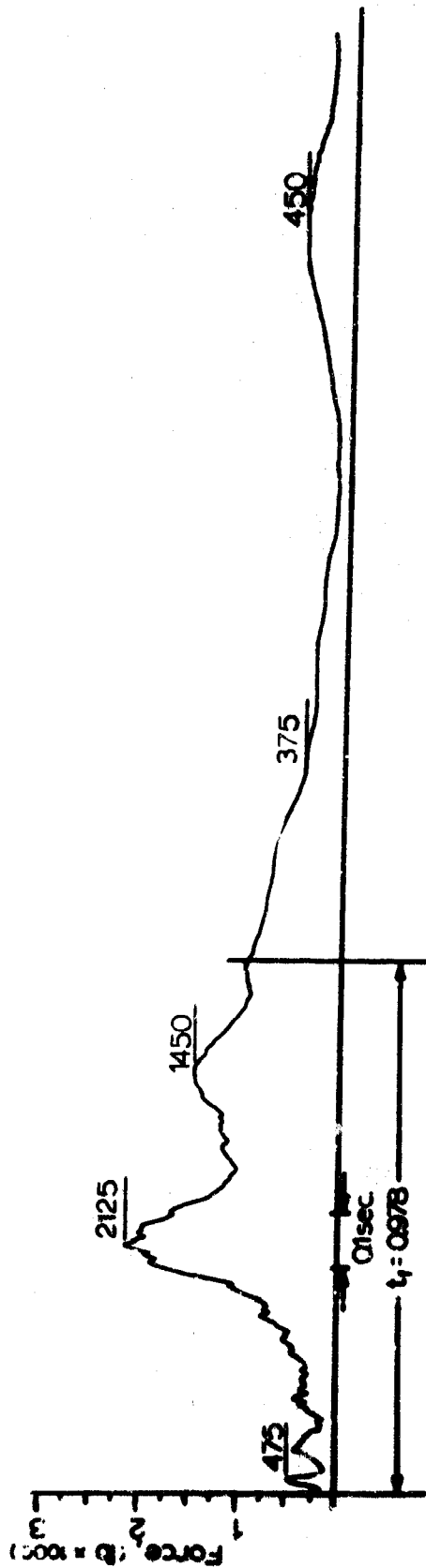


Fig 17 Characteristic Forces and Times of T-10 Parachute Model with Various Internal Canopies



**Fig. 18 Force-Time History of Standard T-10 Parachute,  
Snatch Velocity  $V_s = 221$  fps, Suspended Weight = 210  
lb, Altitude,  $h = 6000$  ft.**

## V. SUMMARY

In parachute model tests, it was shown that the characteristic time of the T-10 parachute can be reduced significantly by means of inflation aids. Shorter opening times are accompanied by higher opening forces. From all inflation aids studied, the internal canopies produced within a certain region the smallest opening forces at a given opening time. The T-10 parachute model had with all but one inflation aid smaller deviations of the characteristic time than the standard configuration.

## VI. REFERENCES

1. Heinrich, H. G. and Niccum, R. J.: A Method to Reduce Parachute Inflation Time with a Minor Increase of Opening Force, WADD Technical Report 60-761, August 1960.
2. Altgelt, R. E.: Low Altitude Airdrop System for Personnel (Exploratory Development), Natick Labs. TR 69-AD, November, 1968, Goodyear Aerospace Corporation.
3. Heinrich, H. G. and Noreen, R. A.: Analysis of Parachute Opening Dynamics with Supporting Wind Tunnel Experiments, AIAA Paper No. 68-924, presented at the AIAA 2nd Aerodynamic Deceleration Systems Conference, El Centro, California, September 23-25, 1968.
4. Berndt, R. J.: Experimental Determination of Parameters for the Calculation of Parachute Filling Times, Jahrbuch 1964 der WGLR.
5. Heinrich, H. G. and Hektner, T. R.: Flexibility as Parameter of Model Parachute Performance Characteristics, December, 1969 (to be published).
6. Haak, Eugene L. and Hovland, Richard V.: Calculated Values of Transient and Steady State Performance Characteristics of Man-Carrying, Cargo, and Extraction Parachutes, AFFDL-TR-66-103, July, 1966.

VII. APPENDIX - FORCE-TIME DIAGRAM  
(Figs 19 through 29)

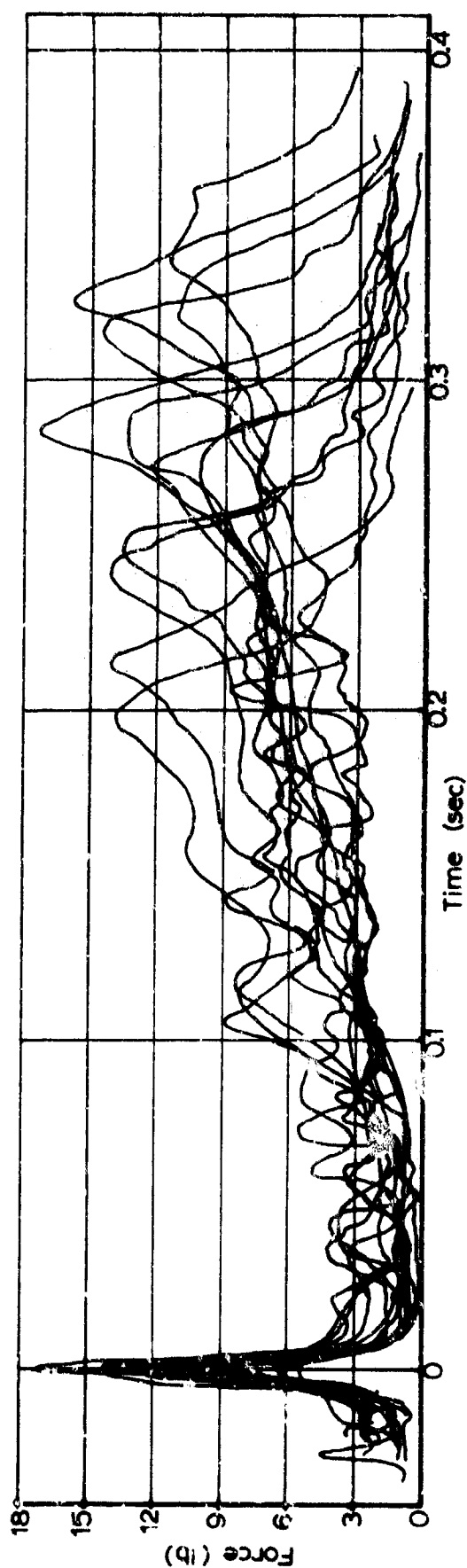


Fig 19 Force Recordings of Standard T-10 Model Parachute,  $D_0 = 41.8$  in.

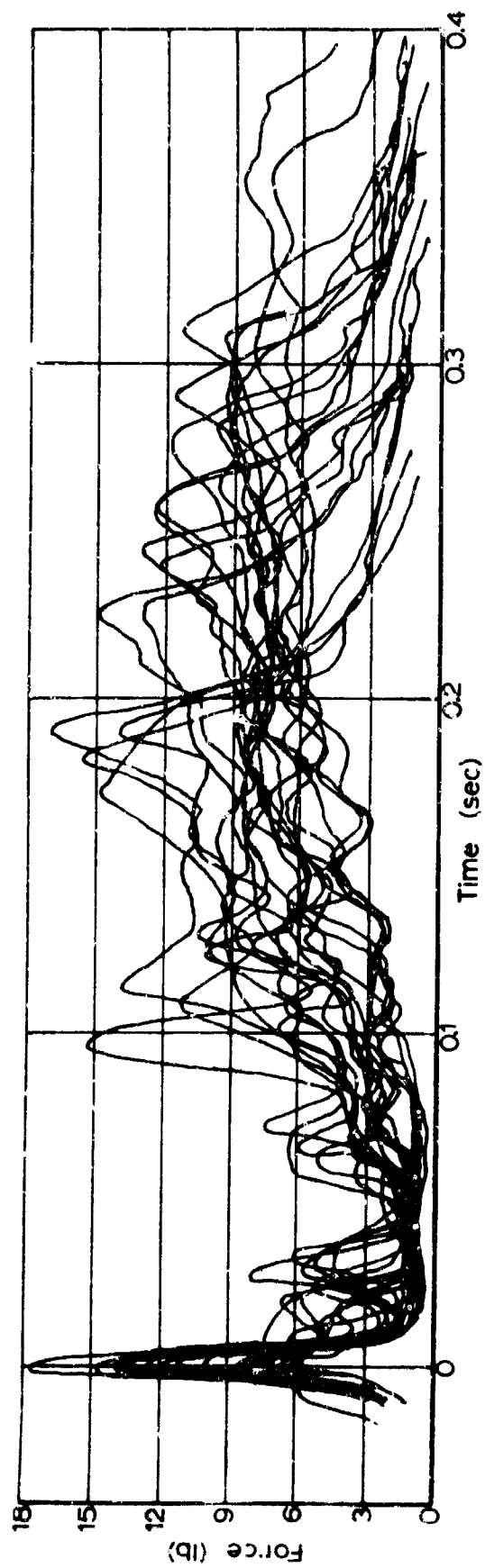


Fig 2.0 Force Recordings of T-10 Model with Centerline,  $L_c/D_o = 1.05$

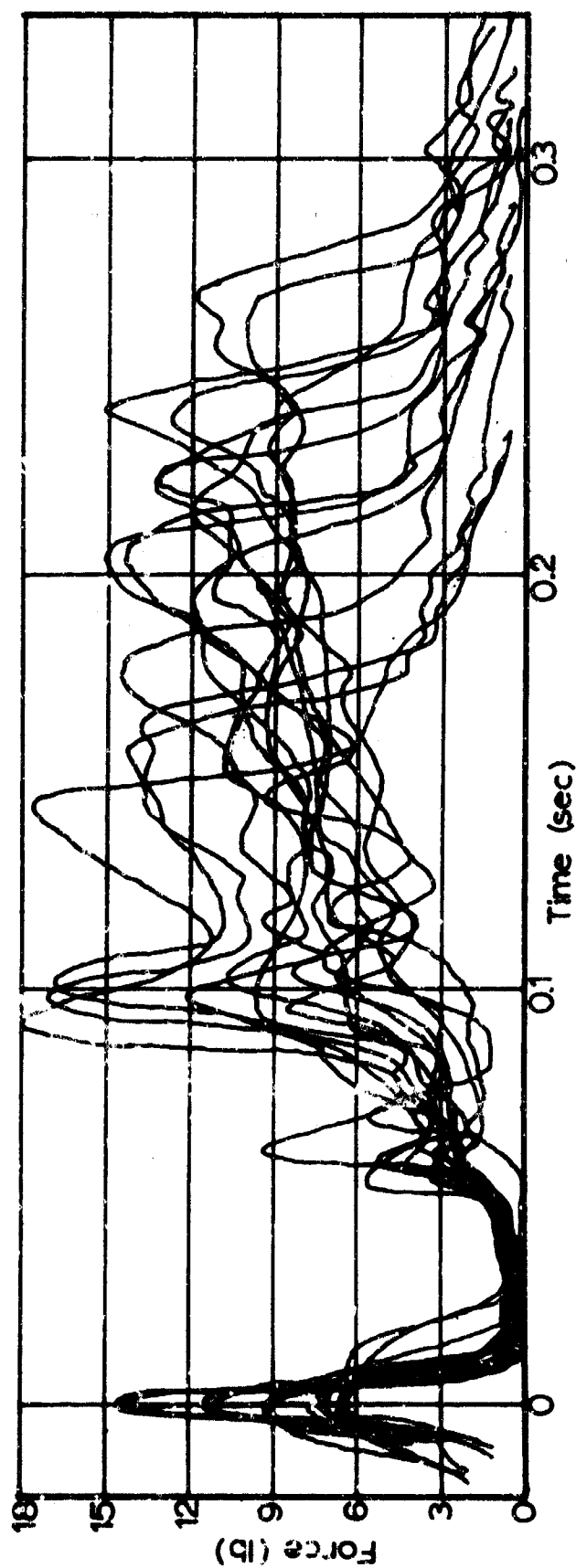


Fig 21 Force Recordings of T-10 Model with Centerline  
 $L_c/D_o = 0.98$



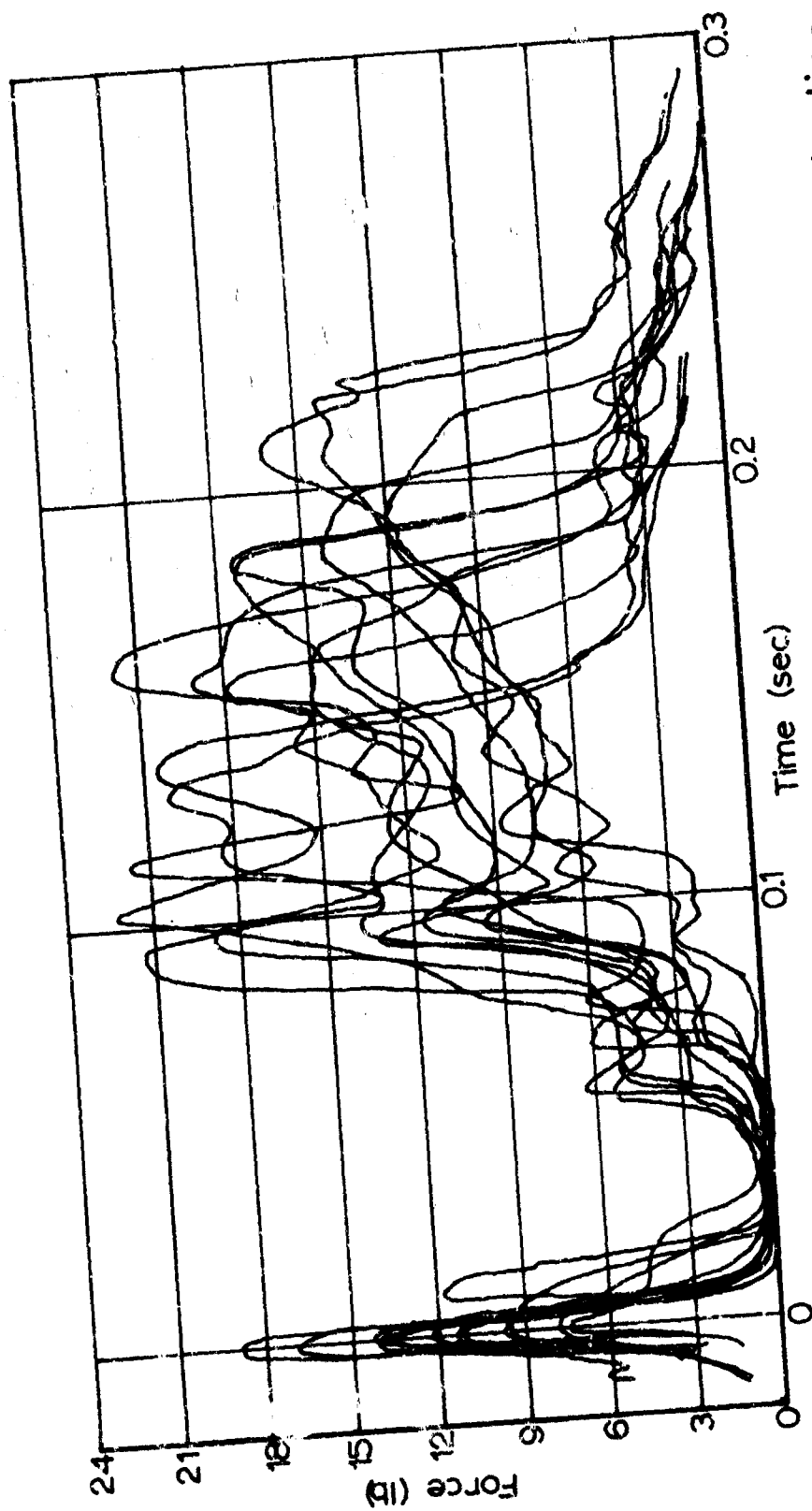
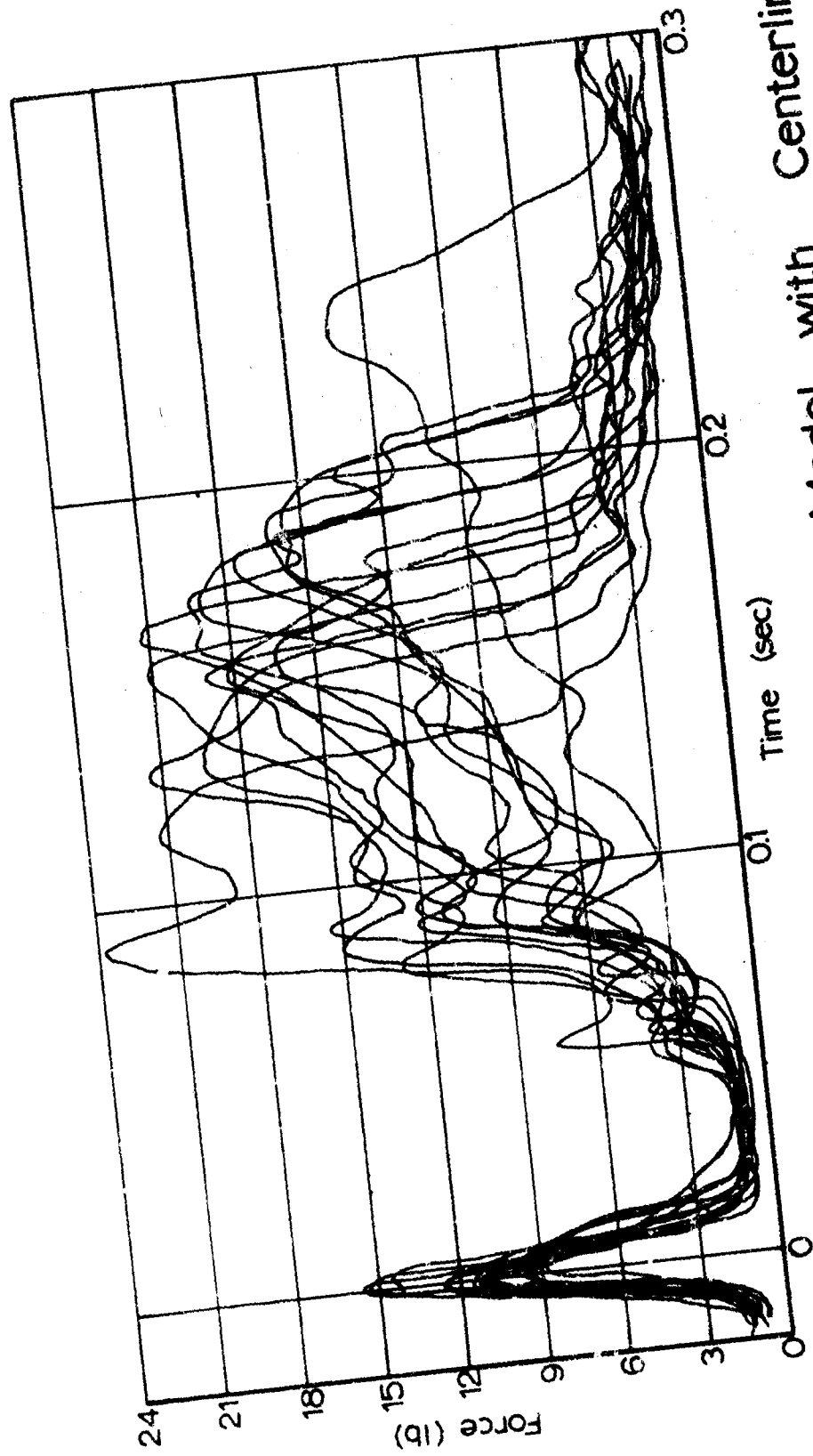


Fig 22 Force Recordings of T-10 Model with Centerline,  
 $L_c/D_o = 0.90$



Centerline, Model with

T-10 Recordings of Force

Fig 23  
 $L_c/D_o = 0.82$

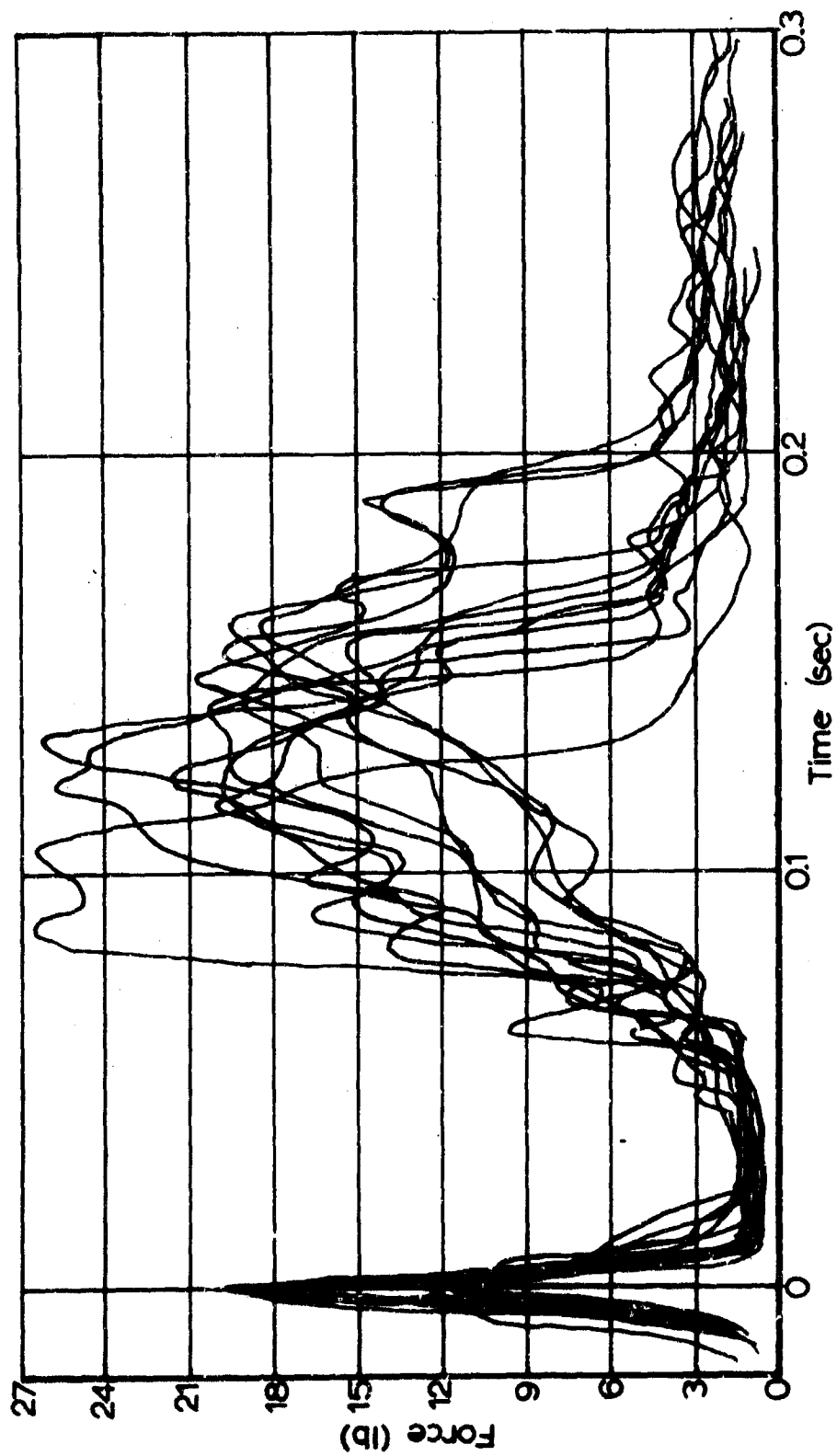


Fig 24 Force Recordings of T-10 Model with Centerline,  
 $L_c/D_o=0.75$

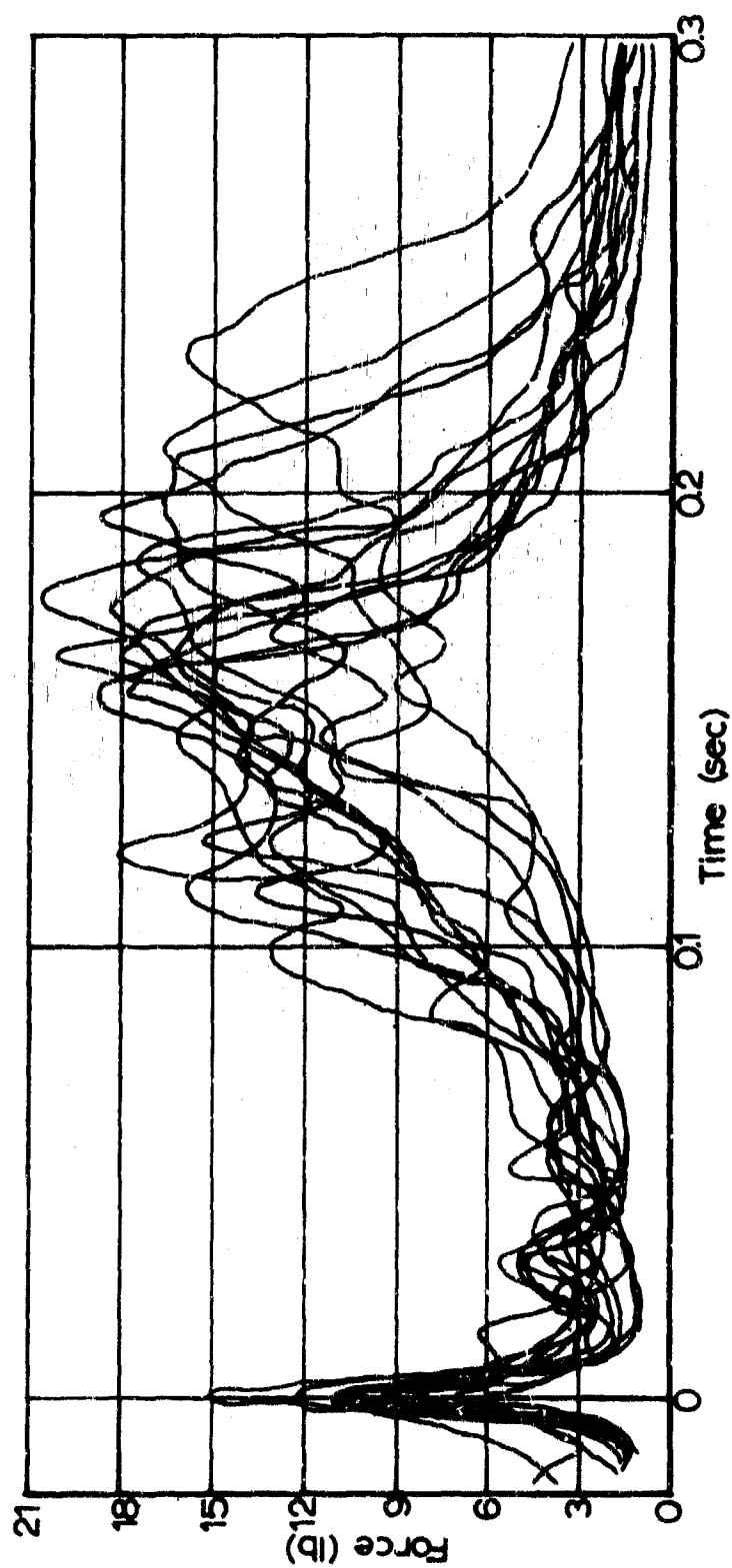


Fig 25 Force Recordings of T-10 Model with Internal Canopy.  $D_I/D_O = 0.14$

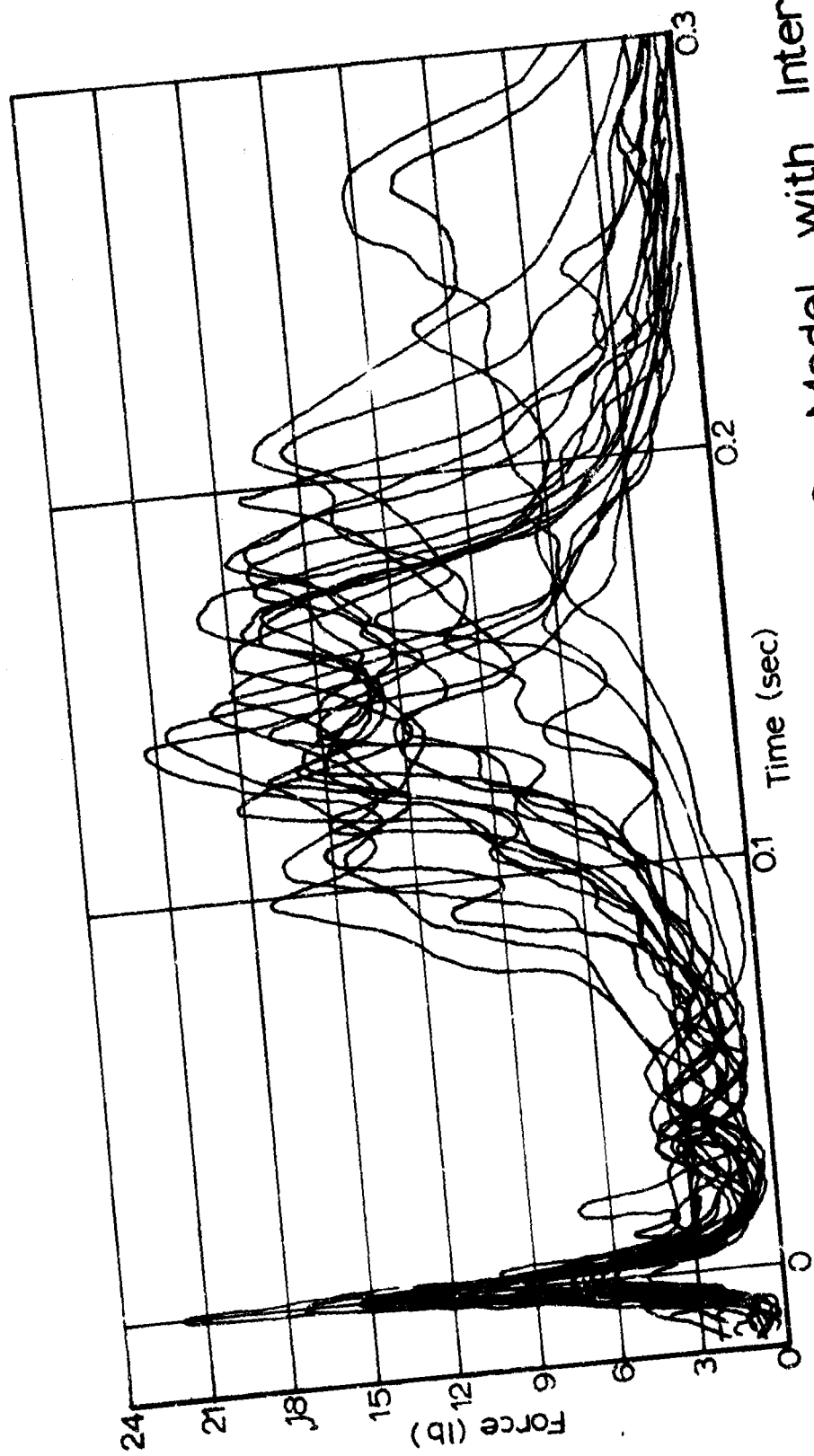


Fig 26 Force Recordings of T-10 Model with Internal Canopy,  $D_1/D_0 = 0.18$

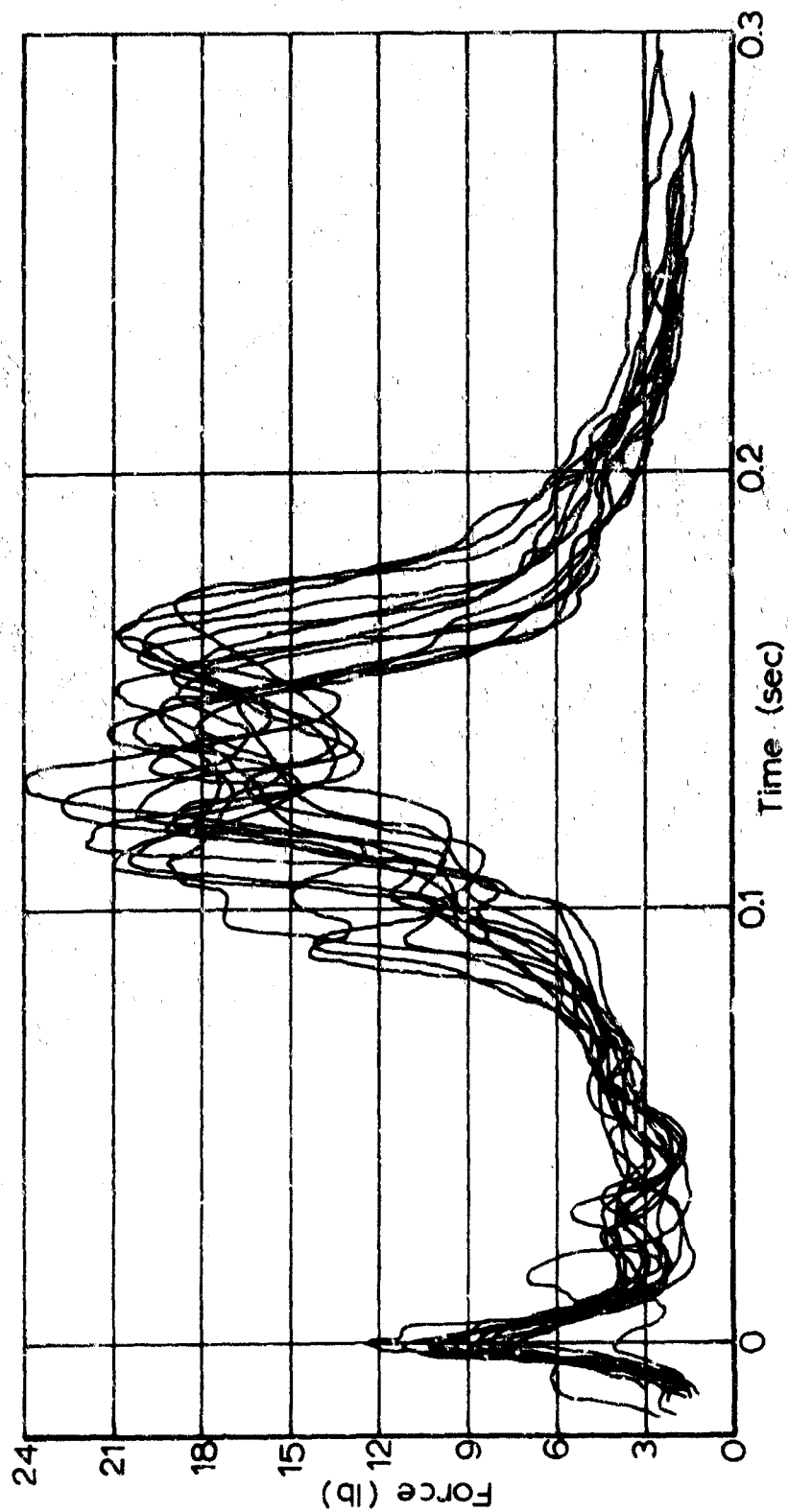


Fig 27 Force Recordings of T-10 Model with Internal Canopy,  $D_i/D_o = 0.23$

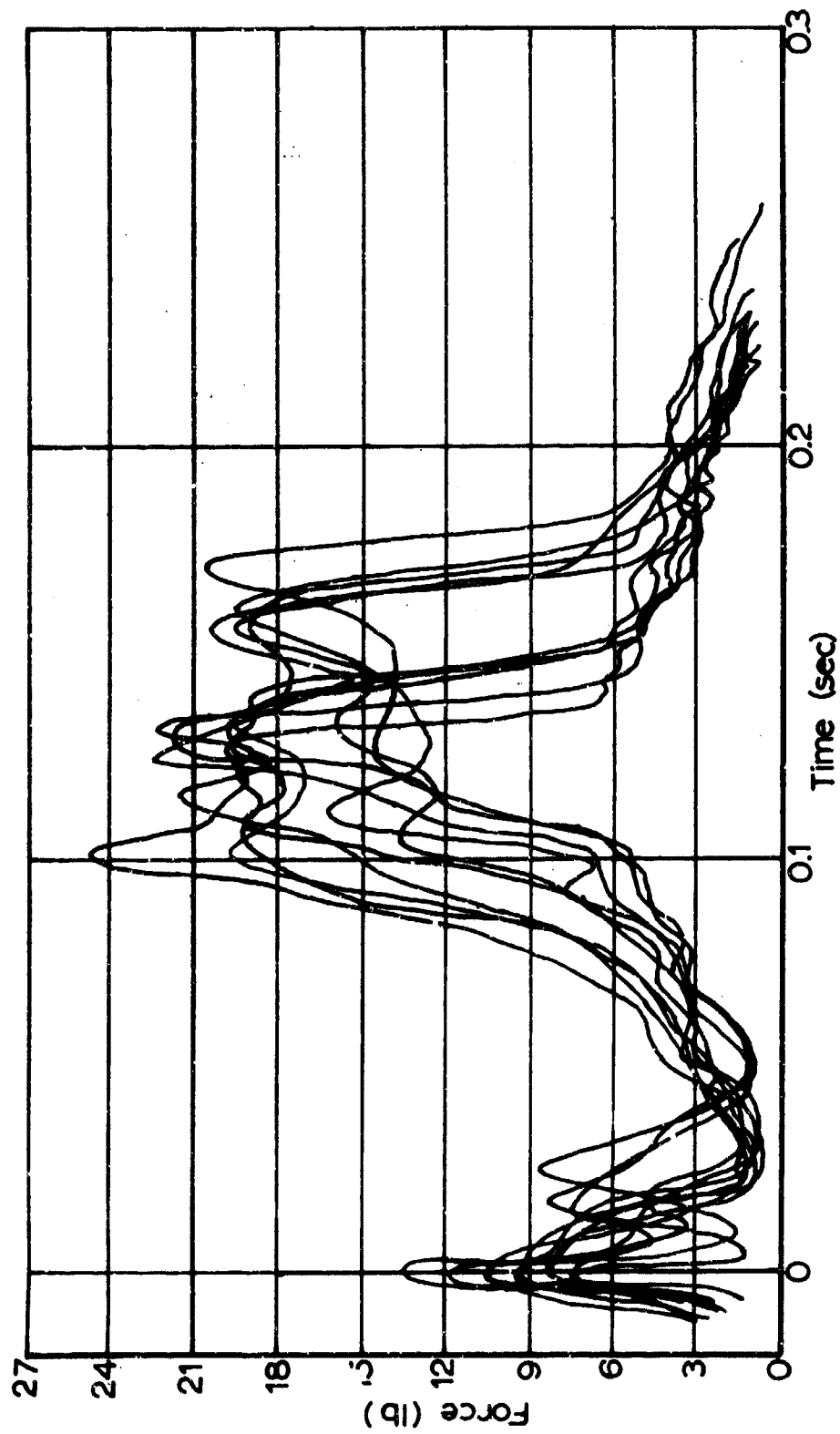


Fig 28 Force Recordings of T-10 Model with Centerline,  
 $L_c/D_o = 0.90$  and Internal Canopy,  $D_1/D_o = 0.18$

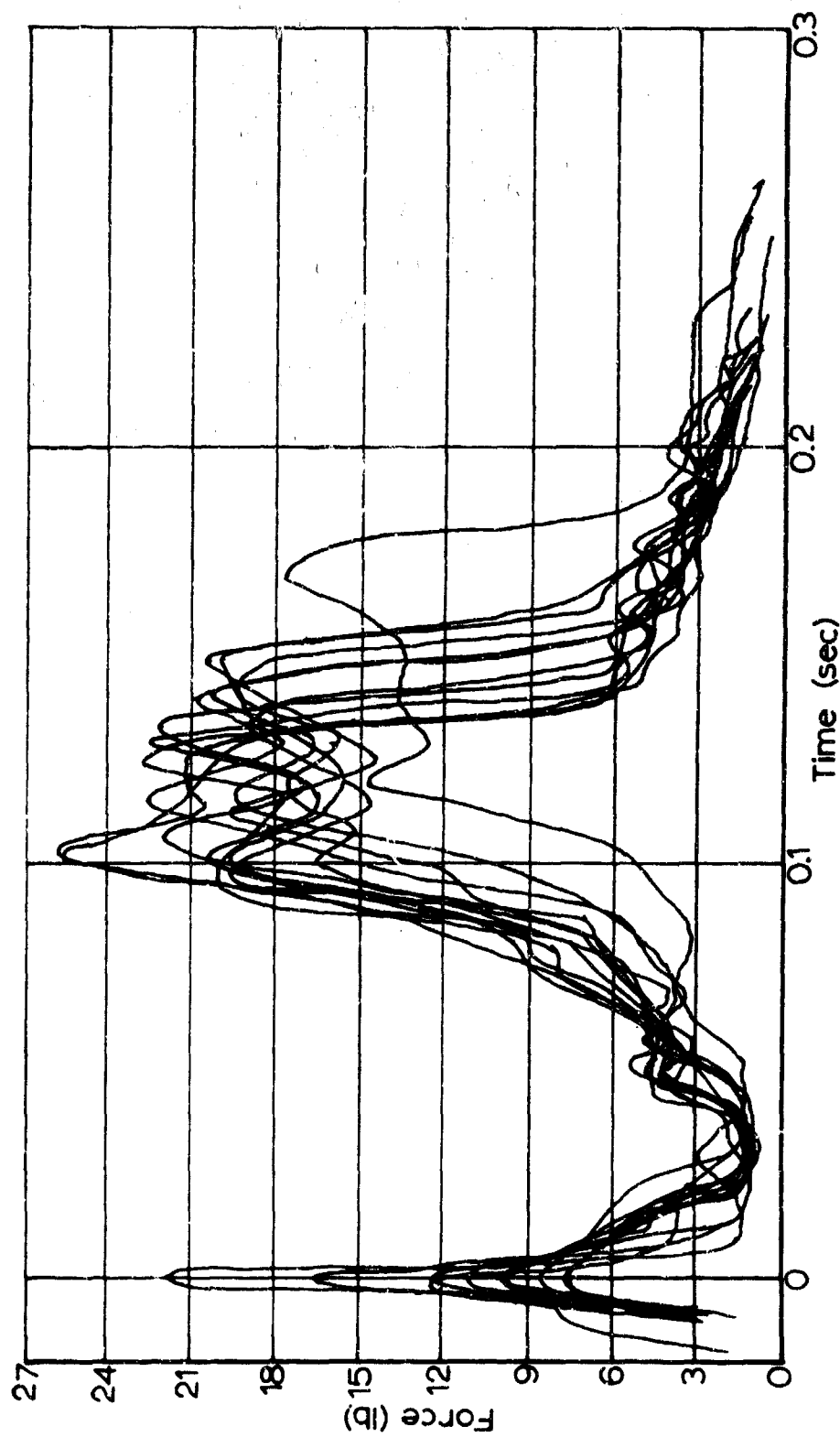


Fig 29 Force Recordings of T-10 Model with  
Centerline,  $L_c/D_o = 0.90$  and Internal Canopy,  
 $D_1/D_o = 0.23$



UNCLASSIFIED

Security Classification

DOCUMENT CONTROL DATA - R&D		
(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)		
1. ORIGINATING ACTIVITY (Corporate author) University of Minnesota Minneapolis, Minn. 55455		2a. REPORT SECURITY CLASSIFICATION Unclassified
		2b. GROUP N/A
3. REPORT TITLE  Opening Dynamics of a T-10 Parachute With Inflation Aids		
4. DESCRIPTIVE NOTES (Type of report and inclusive dates) Final Report June 68 - June 69		
5. AUTHOR(S) (Last name, first name, initial)  Neidrich, Helmut G. Bektner, Thomas R.		
6. REPORT DATE February 70	7a. TOTAL NO. OF PAGES 45	7b. NO. OF REFS 6
8a. CONTRACT OR GRANT NO. F33615-68-C-1227		8b. ORIGINATOR'S REPORT NUMBER(S)  NONE
A. PROJECT NO. 6065  C. Task No. 606503		9b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report)  AFFDL-TR-69-112
10. AVAILABILITY/LIMITATION NOTICES This document is subject to special export controls and each transmittal to foreign governments or foreign nationals may be made only with prior approval of the AF Flight Dynamics Laboratory, Wright-Patterson AFB, Ohio.		
11. SUPPLEMENTARY NOTES	12. SPONSORING MILITARY ACTIVITY AF Flight Dynamics Laboratory AFFDL (FDFR) Wright-Patterson AFB, Ohio 45433	
13. ABSTRACT  The characteristic times and opening forces were studied for various inflation aid configurations of a model T-10 parachute. Finite mass wind tunnel tests were conducted in the horizontal return wind tunnel at a snatch velocity of 70 fps with a suspended load of 1.1 lbs. Relative to results of the standard T-10 parachute, the percentage decrease in the characteristic time and the corresponding percentage increase in the peak force were presented for five centerline, three internal parachutes and two centerline-internal combinations.		

DD FORM 1473

UNCLASSIFIED

Security Classification

UNCLASSIFIED

Security Classification

KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
T-10 Canopy						
Extended Skirt Canopy						
Internal Canopy						
Pulled-Down Vent						
Opening Force						
Filling Time						
Finite Mass Wind Tunnel Tests						

**INSTRUCTIONS**

1. **ORIGINATING ACTIVITY:** Enter the name and address of the contractor, subcontractor, grantee, Department of Defense activity or other organization (*corporate author*) issuing the report.

2a. **REPORT SECURITY CLASSIFICATION:** Enter the overall security classification of the report. Indicate whether "Restricted Data" is included. Marking is to be in accordance with appropriate security regulations.

2b. **GROUP:** Automatic downgrading is specified in DoD Directive 5200.10 and Armed Forces Industrial Manual. Enter the group number. Also, when applicable, show that optional markings have been used for Group 3 and Group 4 as authorized.

3. **REPORT TITLE:** Enter the complete report title in all capital letters. Titles in all cases should be unclassified. If a meaningful title cannot be selected without classification, show title classification in all capitals in parenthesis immediately following the title.

4. **DESCRIPTIVE NOTES:** If appropriate, enter the type of report, e.g., interim, progress, summary, annual, or final. Give the inclusive dates when a specific reporting period is covered.

5. **AUTHOR(S):** Enter the name(s) of author(s) as shown on or in the report. Enter last name, first name, middle initial. If military, show rank and branch of service. The name of the principal author is an absolute minimum requirement.

6. **REPORT DATE:** Enter the date of the report as day, month, year, or month, year. If more than one date appears on the report, use date of publication.

7a. **TOTAL NUMBER OF PAGES:** The total page count should follow normal pagination procedures, i.e., enter the number of pages containing information.

7b. **NUMBER OF REFERENCES:** Enter the total number of references cited in the report.

8a. **CONTRACT OR GRANT NUMBER:** If appropriate, enter the applicable number of the contract or grant under which the report was written.

8b, 8c, & 8d. **PROJECT NUMBER:** Enter the appropriate military department identification, such as project number, subproject number, system numbers, task number, etc.

9a. **ORIGINATOR'S REPORT NUMBER(S):** Enter the official report number by which the document will be identified and controlled by the originating activity. This number must be unique to this report.

9b. **OTHER REPORT NUMBER(S):** If the report has been assigned any other report numbers (*either by the originator or by the sponsor*), also enter this number(s).

10. **AVAILABILITY/LIMITATION NOTICES:** Enter any limitations on further dissemination of the report, other than those imposed by security classification, using standard statements such as:

- (1) "Qualified requesters may obtain copies of this report from DDC."
- (2) "Foreign announcement and dissemination of this report by DDC is not authorized."
- (3) "U. S. Government agencies may obtain copies of this report directly from DDC. Other qualified DDC users shall request through \_\_\_\_\_."
- (4) "U. S. military agencies may obtain copies of this report directly from DDC. Other qualified users shall request through \_\_\_\_\_."
- (5) "All distribution of this report is controlled. Qualified DDC users shall request through \_\_\_\_\_."

If the report has been furnished to the Office of Technical Services, Department of Commerce, for sale to the public, indicate this fact and enter the price, if known.

11. **SUPPLEMENTARY NOTES:** Use for additional explanatory notes.

12. **SPONSORING MILITARY ACTIVITY:** Enter the name of the departmental project office or laboratory sponsoring (*paying for*) the research and development. Include address.

13. **ABSTRACT:** Enter an abstract giving a brief and factual summary of the document indicative of the report, even though it may also appear elsewhere in the body of the technical report. If additional space is required, a continuation sheet shall be attached.

It is highly desirable that the abstract of classified reports be unclassified. Each paragraph of the abstract shall end with an indication of the military security classification of the information in the paragraph, represented as (TS), (S), (C), or (U).

There is no limitation on the length of the abstract. However, the suggested length is from 150 to 225 words.

14. **KEY WORDS:** Key words are technically meaningful terms or short phrases that characterize a report and may be used as index entries for cataloging the report. Key words must be selected so that no security classification is required. Identifiers, such as equipment model designation, trade name, military project code name, geographic location, may be used as key words but will be followed by an indication of technical context. The assignment of links, rules, and weights is optional.

UNCLASSIFIED

Security Classification

END

6/9/71